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PULMONARY DISEASE AMONG MINERS IN THE JOPLIN DISTRICT, MISSOURI

AND ITS RELATION TO ROCK DUST IN THE MINES

A PRELIMINARY REPORT

BY

A. J. LANZA
AND
EDWIN HIGGINS

WASHINGTON
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PREFACE.

That the inhalation of sharp particles of dust injures the mucous membrane of the lungs, and in this way lessens the resistance of the lungs to pathologic germs, especially the bacilli of pulmonary tuberculosis, has been proved by investigations of morbidity among workmen in dusty trades and by study of the prevalence of lung diseases in South Africa and other foreign countries. The matter is one of deep public concern, and attention has been called to it from time to time in publications of the Bureau of Mines. Until recently, however, the bureau has been unable from lack of necessary funds to prosecute investigations comparable with those that have been carried on abroad.

Recently, with a view to affording some measure of relief through suggested educational work and through State legislation, the bureau has undertaken, in cooperation with the Bureau of the Public Health Service, preliminary investigations of the production of dust in metal mines in various parts of the United States and the relation of the prevalence of dust to silicosis, or miner's consumption, and pulmonary tuberculosis among miners. Passed Assistant Surgeon A. J. Lanza has been detailed to the Bureau of Mines and is now working in cooperation with Edwin Higgins, a mining engineer of the bureau, in making a survey of conditions in various metal-mining districts of the United States. The following report deals with the prevalence of tuberculosis among the miners of the Joplin district, Missouri. Reports on other districts will be published as investigations are completed.

VAN. H. MANNING.

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PULMONARY DISEASE AMONG MINERS IN THE JOPLIN DISTRICT, MISSOURI, AND ITS RELATION TO ROCK DUST IN THE MINES; A PRELIMINARY REPORT.

By A. J. Lanza and Edwin Higgins.

INTRODUCTION.

This report deals with sanitary conditions, more especially the prevalence of siliceous rock dust, in the lead and zinc mines of the Joplin district and the bearing of these conditions on pulmonary diseases of the miners. Field work was carried on in the period between November 7 and December 6, 1914, in Jasper, Lawrence, Newton, and Greene Counties, Mo., and in outlying districts in Kansas and Oklahoma, the most time, however, being spent in the "sheet-ground" mines of Jasper County. Owing to the great number of cases of tuberculosis and the fact that the miners as a class are not migratory, the Joplin district presents a most favorable field for studying the effects of certain sanitary conditions and their bearing on the health of the miner.

The writers take this opportunity for thanking the mine officials of the Joplin district for the courteous treatment accorded them during this investigation; also the three State mine inspectors, Ira L. Burch, Walter W. Holmes, and C. M. Harlan, who rendered most valuable assistance in the examination of the mines.

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THE PREVALENCE OF TUBERCULOSIS IN THE JOPLIN DISTRICT.

By A. J. Lanza.

INTRODUCTION.

The miners of the Joplin district and their families are practically all of American stock. Many of them are only one or two generations removed from the Tennessee mountains and the Arkansas farming country, and as they drift into mining work are most often fresh from Missouri farms. These people are intelligent, independent, and industrious; as a rule they marry young, and large families are frequent. Their efficiency, as far as labor in the mines is concerned, is high and probably not exceeded in any other mining community in this country. Many of them prosper in mining, and it is a common saying in southwestern Missouri that every miner is a prospective operator. Although the sanitary environment of their homes often leaves much to be desired as regards its bearing on public health, the faults are essentially due to a lack of knowledge of the effect of certain practices. It is probable that sanitary education would not only be well received in the communities in the Joplin district, but would work a great deal of good.

EFFORTS TO COMBAT TUBERCULOSIS.

In recent years there has been an unusual prevalence of pulmonary tuberculosis and a high death rate from it among the metal miners in southwestern Missouri. This condition has attracted considerable attention and has caused no little alarm in that part of the country. Various efforts made to ascertain and abate the causes of the trouble have resulted in the formation of the Jasper County Antituberculosis Society on the one hand and various committees of mine operators on the other. The Antituberculosis Society, besides gathering statistics, established in October, 1913, a visiting-nurse service, which has proved very valuable. The mine operators have succeeded in the past two years in making many substantial improvements in working conditions underground, and the State mine inspectors have made the betterment of such conditions one of their especial functions, though handicapped by the lack of any laws on the subject.

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APPEARANCE OF TUBERCULOSIS AND ITS CAUSES.

It seems to be the general opinion in Jasper County that lung diseases became more prevalent after the beginning of active mining in the sheet ground, in the early eighties, and that the flint dust from drilling and other mine operations is largely responsible for this condition. Reasoning from cause to effect is apt to be unreliable where tuberculosis is concerned, especially in dealing with specific cases. The opening of the sheet ground brought many new men into the district until in 1909 there were upward of 12,000 men working in the mines. At present (December, 1914) the number of men engaged in this work has diminished to about one-half that number. The fact that cases of tuberculosis are not reported by physicians when first treated and the well-known habit of consumptives to travel before they die from the place where they contracted their disease makes it impossible from the death records alone to determine the exact number of cases of tuberculosis contracted in any given locality, and these records are the only official ones obtainable.

As establishing the death rate for tuberculosis in the entire State, the State records may be used. As indicating the actual amount of tuberculosis contracted in any defined area therefrom, the death records are not of much service and will not be of as much value as data compiled from first-hand knowledge. Such data have been compiled in part by the Jasper County Antituberculosis Society and necessarily differ from those of the State board of health, inasmuch as they credit to Jasper County cases of tuberculosis originating there but dying elsewhere. This difference, rightly interpreted, does not detract from either group of statistics.

However, both the records of the State board of health and of the Jasper County Antituberculosis Society demonstrate an unusual prevalence of tuberculosis in that county. Furthermore, allowing for various differences of opinion, inaccuracies, errors, and exaggerations, all unavoidable, an impartial investigator can not but conclude that when working conditions in any locality are such as to expose the workers to a hard, flinty, insoluble rock dust, and, when among those workers there is a high death rate from pulmonary tuberculosis, that there is a definite connection between the dust and the disease and that the dust is largely responsible for the disease—not entirely responsible for all pulmonary disease, but a prime factor in its causation.

RECORDS OF FATALITIES FROM TUBERCULOSIS.

The records of the State board of health for the calendar year 1912 show 180 deaths from pulmonary tuberculosis in Jasper County, which represent a death rate from this disease of 200.8 per 100,000 population.

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According to the Jasper County Antituberculosis Society, on the other hand, during the calendar year 1912 there were 720 deaths among miners who had worked two years or more underground in Jasper County. Of this number of deaths not more than 12 were from pneumonia, which was in some cases a terminal infection in tuberculous subjects. Not all of these 720 deaths, however, occurred in Jasper County; some were in adjoining counties of Missouri and Kansas, where the men had gone presumably on account of their health. By keeping track of sick miners who left the district and keeping in touch with the miners' families and by examining newspapers printed in adjoining counties and States the Antituberculosis Society believes it was able to obtain a record of the death of nearly every miner who had contracted tuberculosis in Jasper County and had moved away.

During 1913 this follow-up work by the Jasper County Antituberculosis Society was not continued, but a visiting nurse, whose services were obtained in October, 1913, has stated that from October, 1913, to October, 1914, she visited in Webb City and vicinity 341 cases of tuberculosis, of whom 112 had died up to December, 1914. All these cases were miners or members of their families. From personal experience and long residence in the district this nurse estimates that she sees about one-fifth of the total number of cases in her field, which is Webb City and the immediate neighborhood.

Additional evidence of the prevalence of tuberculosis in Jasper County is afforded by the following statement by the Antituberculosis Society:

> On a petition ("Wet *v.* Dry") recently filed by property owners in a small town in Jasper County there were the names of 132 widows. The husbands of five of these had died from accidents, leaving 127 whose husbands had died from tuberculosis.

Furthermore, various mine operators expressed the belief that 50 to 60 per cent of their men had lung trouble, as evidenced by cough, shortness of breath, and lessened ability to work. An operator of one of the largest mines in the district stated that since 1907 he had employed 750 men. In May, 1914, the time of making his statement publicly, he said that only about 50 of these were still living, and all the others except not more than a dozen were said to have died from tuberculosis.

Statistics of the State board of health are available for the years 1911, 1912, and 1913. In Table 1 following, Jasper County is compared with Jackson County, including Kansas City, with St. Louis alone, and with Buchanan County, including St. Joseph, as these large cities would be apt to have an average death rate from pulmonary tuberculosis. Greene County, including Springfield, is included as approximating Jasper County in size and location. St. Francois County, in which are many lead mines of the southeastern Missouri field, is included in the comparison as another metal-mining county.

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TABLE 1.—*Deaths from tuberculosis during 1911, 1912, and 1913, compiled from figures of the Missouri State Board of Health.*

County.	Population (1910).	Total number of deaths.	Deaths from pulmonary tuberculosis.		
			Number.	Number per 100,000 population.	Proportion of total.
1911.					
					Per cent.
Jasper (includes Webb City and Joplin)	89,673	1,215	180	200.8	14.08
St. Francois	35,783	530	63	176+	11.8
Greene (includes Springfield)	63,831	895	83	130+	9.27
Jackson (includes Kansas City)	283,522	4,381	406	143.1	9.33
St. Louis (city)	687,029	10,779	945	137.5	8.75
Buchanan (includes St. Joseph)	92,920	1,167	88	94.8	7.54
1912.					
Jasper (includes Webb City and Joplin)	89,673	1,190	180	200.8	15.1
St. Francois	35,783	436	51	142.9	11.6
Greene (includes Springfield)	63,831	866	82	128.5	9.46
Jackson (includes Kansas City)	283,522	4,450	404	142.4	9.07
St. Louis (city)	687,029	10,607	948	152.5	8.93
Buchanan (includes St. Joseph)	92,920	1,249	104	111.9	8.03
1913.					
Jasper (includes Webb City and Joplin)	89,673	1,324	206	229.7	15.5
St. Francois	35,783	518	68	190+	13.1
Greene (includes Springfield)	63,831	847	63	99.2	7.4
Jackson (includes Kansas City)	283,522	4,487	396	139.6	8.8
St. Louis (city)	687,029	10,972	987	143.6	9.1
Buchanan (includes St. Joseph)	92,920	1,364	108	116.2	7.9

This table shows that in all three years Jasper County leads the other counties mentioned by a considerable margin, both in the number of deaths per 100,000 of population and in the percentage of deaths due to pulmonary tuberculosis. Also there is a marked increase in the death rate from 1911 to 1913, but this may in part be accounted for by the yearly improvement in the reporting of vital statistics. It is also noteworthy that St. Francois, a metal-mining county, although far below Jasper County, leads all the others in the number of deaths from pulmonary tuberculosis per 100,000 of population. We would expect comparatively high figures for both St. Francois and Jasper Counties, each being a metal-mining community, but the figures for Jasper County are unusually high.

The tabulated figures, indicating the prevalence of pulmonary tuberculosis, are of course based on a system of death reports only. When we are able to trace the incidence of disease at first hand, regardless of where the sick die, but with a knowledge of where, in all probability, their disease is contracted, we get figures as quoted by the Jasper County Antituberculosis Society.

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Interesting information is afforded by various insurance companies. One of the largest insurance companies in the United States, which also does an industrial business, requires that in Webb City and the immediate neighborhood all applicants for industrial insurance over 10 years of age be examined by an accredited physician as for ordinary insurance. Such a rule is in operation in only one or two other districts, and was occasioned by the number of death claims in which pulmonary tuberculosis was given as a cause of death. Another industrial insurance company doing a large business among miners and their families estimates that at least 90 per cent of rejections and 75 per cent of death claims are due to pulmonary tuberculosis.

PHYSICAL EXAMINATION OF MINERS.

Besides obtaining data similar to the above, it was deemed advisable to make physical examinations of such miners as might care to take advantage of the opportunity. In all, in Webb City and Carterville, 93 miners presented themselves for examination. They were carefully examined and a record kept of each examination. Of these 93 men, 64 showed plain and definite evidence of pulmonary disease, 3 were suffering from nonpulmonary disease, and 26 were seemingly well. Of the 64 sick men, 22 had stopped work on account of their health, the remaining 42 still working underground. Moreover, of these 64 men, 39 had the classical symptoms (night sweats, cough, hemorrhage, loss of weight, fever) of pulmonary tuberculosis; the physical signs of the other 25 men were not such as to justify a diagnosis of tuberculosis on one examination. All of these 25 had noticeable dyspnea, cough, and lessened ability to work. Eleven of the 25 showed signs of lung injury, whereas 14, in spite of marked subjective symptoms, presented no definite sign of tuberculosis on physical examination, their condition resembling rather silicosis, or miners' consumption. (See comments on rock dust, p. 37.)

In presenting these results of examinations, it is well to state that the figures can not be considered as showing the percentage of tuberculosis among miners generally in the county, as those who applied for examinations probably had symptoms which made them suspect they had the disease. That so large a number of men applied in so short a time, however, is additional indication of an undue prevalence of lung diseases among the miners.

It is evident, then, that there is a general agreement among these several figures and statements, and, taken as a whole, they supply evidence to support the general opinion as to the undue prevalence of tuberculosis in southwest Missouri and the need of remedial measures.

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THE MINES OF THE JOPLIN DISTRICT.

By Edwin Higgins.

INTRODUCTION.

Although many details of mining practice in the Joplin district are of interest to the engineer, only such subjects are considered in this paper as seem necessary for an understanding of the causes of insanitary conditions in and about the mines. In the course of this investigation, 30 representative mines were examined. The notes on geology and mining methods, although they apply to a certain extent to the entire district, are confined chiefly to the sheet-ground deposits in the vicinity of Joplin, Webb City, Carterville, and other smaller near-by towns in Jasper County, Mo. It is only in these mines that rock dust is present in appreciable quantities.

The writer is indebted to various officials of the Bureau of Mines; to George S. Rice, chief mining engineer, for assistance in the form of valuable suggestions regarding the conduct of this investigation; to G. A. Burrell, chemist, for assistance in perfecting the rock-dust sampling device and for supervision of the analytical work on air samples; to A. C. Fieldner, chemist, who directed the chemical and sizing tests and the weighing of the rock-dust samples; and to Reinhardt Thiessen, assistant chemist, who performed the microscopic work.

GENERAL INFORMATION.

As a matter of general interest Table 2, showing the number of employees and wages paid, and the tonnage and value of ores mined during 1913 [a] is herewith submitted. It may be noted from this table that the total number of employees in Greene, Jasper, Lawrence, and Newton Counties in 1913 was 6,351.

Table 2.—*Number of employees, wages paid, and tonnage and value of ores (concentrates) mined in the Joplin district during 1913.*

County.	Number of miners employed.	Average daily wage.	Number of other employees.	Average daily wage.	Total number of employees.	Zinc (blende).	
						Amount mined.	Value.
						Tons.	
Greene	30	$2.14	17	$2.45	47	900	$42,156
Jasper	4,242	2.67	1,746	2.64	5,988	226,738	9,755,487
Lawrence	33	2.08	51	2.05	84	50	841
Newton	138	2.47	94	2.46	232	2,461	112,982
Total	4,443	.....	1,908	.....	6,351	230,149	9,911,466

[a] Taken from the Twenty-seventh Annual Report of the Bureau of Mines, Mining, and Mine Inspection of the State of Missouri.

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TABLE 2.—*Number of employees, wages paid, and tonnage and value of ores (concentrates) mined in the Joplin district during 1913*—Continued.

County.	Zinc silicate (calamine.)		Lead (galena).		Dry bone (smithsonite).		Total value of all minerals mined.
	Amount mined.	Value.	Amount mined.	Value.	Amount mined.	Value.	
	Tons.		*Tons.*		*Tons.*		
Greene	.....	.....	65	$3,511	.....	.....	$45,667
Jasper	162	$3,460	36,031	1,817,329	6	$150	11,576,426
Lawrence	764	16,080	13	626	2	45	17,592
Newton	4,712	96,091	1,643	99,374	32	948	309,395
Total	5,638	115,631	37,752	1,920,840	40	1,143	11,949,080

Table 3 shows the number and location of the mines that were active at the time of this investigation and the number of men employed on the surface and underground. It may be noted that in all there were 51 sheet-ground operations, employing 3,249 men; and 118 operations in disseminated and other types of deposits, employing 3,049 men. The principal activity in sheet-ground mining is in the vicinity of Carterville and Webb City.

TABLE 3.—*Location and number of employees of active mines in southwestern Missouri in November, 1914.*

Location.		Number of active operations, "sheet ground."	Number of employees, "sheet ground."		Number of active operations, disseminated and others.	Number of employees—disseminated and other mines.	
Town.	County.		Surface.	Underground.		Surface.	Underground.
Joplin	Jasper	9	124	370	38	417	727
Webb City	do	12	180	530	6	44	102
Carterville	do	19	283	1,055	12	75	140
Duenweg	do	4	71	217	18	105	171
Neck City	do	.....	.....	.....	9	112	230
Oronogo	do	2	48	140	.....	.....	.....
Prosperity	do	3	36	90	2	6	11
Carthage	do	.....	.....	.....	2	22	44
Carl Junction	do	1	20	35	1	6	15
Alba	do	.....	.....	.....	4	38	66
Porto Rico	do	1	12	38	1	9	11
Sarcoxie	do	.....	.....	.....	1	9	15
Spring City	Newton	.....	.....	.....	6	86	177
Granby	do	.....	.....	.....	8	61	127
Melva	Taney	.....	.....	.....	1	10	20
Springfield	Greene	.....	.....	.....	3	23	45
Aurora	Lawrence	.....	.....	.....	6	40	85
Total		51	774	2,475	118	1,063	1,986

Several counties in southwestern Missouri and closely adjoining parts of Kansas and Oklahoma are shown in figure 1. Figure 2 shows the territory from Oronogo, Jasper County, Mo., southeasterly through Webb City, Carterville, Prosperity, Porto Rico, and Duenweg, wherein are situated a large proportion of the sheet-ground operations.

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GEOLOGY AND ORE DEPOSITS.

Much has been written regarding the geology of the Joplin district.[a] For the purpose of this report, it seems necessary to describe briefly the nature of the rock in which mining is conducted, as this feature bears directly on the character of the rock dust formed. The ore deposits may be divided broadly into: (*a*) Those that have been termed sheet-ground deposits (in chert), and (*b*) those in which the ore occurs in "runs" or irregular pockets (in limestone). As far as the prevalence of rock dust is concerned, the latter deposits need not be seriously considered. In Jasper County, where are the greater number of sheet-ground mines, the ore deposits occur chiefly in the Grand Falls member of the Boone chert, a formation in the Mississippian series of the Carboniferous system. The sheet-ground deposits consist of stratified layers of bedded chert, the layers ranging in thickness from a few inches to 30 inches and lying almost horizontally. The chert beds range from 6 to 30 and sometimes 45 feet in thickness. Zinc blende, or jack (sphalerite), with which is associated varying small quantities of lead sulphide (galena), lies in the crevices and partings of the chert. In places lesser amounts of minerals are found disseminated throughout the layers. The principal sheet-ground deposits lie at an average depth of 180 feet, and the gangue material is made up entirely of the Boone chert mentioned.

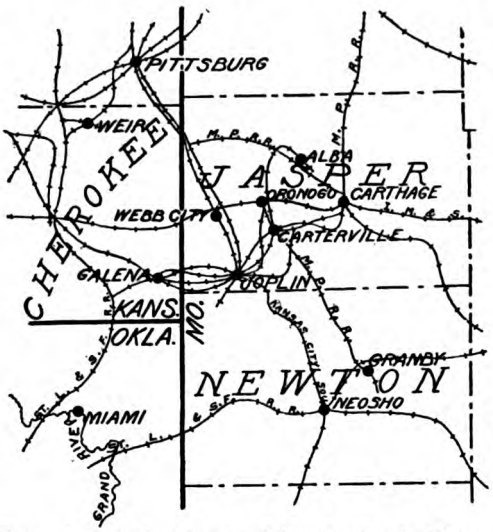

FIGURE 1.—Map of southwestern Missouri and parts of Kansas and Oklahoma.

The typical Grand Falls chert of the Boone formation[b] is of the splintery, fresh, unaltered appearing type known as "live" or "butcher-knife" flint. Much of it has been thoroughly crushed in place and recemented with a darker bluish siliceous cement, the original bed remaining practically undisturbed. Where the chert has been subjected to rather sharp deformation instead of suffering simple brecciation, it loses its bedded character and becomes gnarled and knotted in structure, weathering with a very rough surface.

[a] Schmidt, A., and Leonard, A., Lead and zinc regions of southwestern Missouri: Missouri Geol. Survey, vol. 1, 1874, pp. 381–502; Winslow, A., Lead and zinc deposits: Missouri Geol. Survey, vols 6, 7, 1894; Jenney, W. P., Lead and zinc deposits of the Mississippi Valley: Trans. Am. Inst. Min. Eng., vol. 22, 1894, pp. 171–225, 642–646; Bain, H. F., Van Hise, C. R., and Adams, G. I., Preliminary report on the lead and zinc deposits of the Ozark region: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 23–228; Smith, W. S. T., Lead and zinc deposits of the Joplin district, Missouri-Kansas: U. S. Geol. Survey Bull. 213, 1903, pp. 197–204; Buckley, E. R., and Buehler, H. A., Geology of the Granby area: Missouri Bureau Geology and Mines, 2d ser., vol. 4, 1906; Haworth, Erasmus, Crane, W. R., Rogers, A. F., and others, Special report on lead and zinc: Univ. Geol. Survey Kansas, vol. 7, 1904.

[b] Siebenthal, C. E., Joplin District, Mo., U. S. Geol. Survey Folio 148, 1907.

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This description of the chert is given to draw attention to the character of the rock as bearing on the character of the rock dust formed.

The "runs" or irregular bodies of ore occur in both hard and soft ground. As a rule they lie at shallower depths (but sometimes

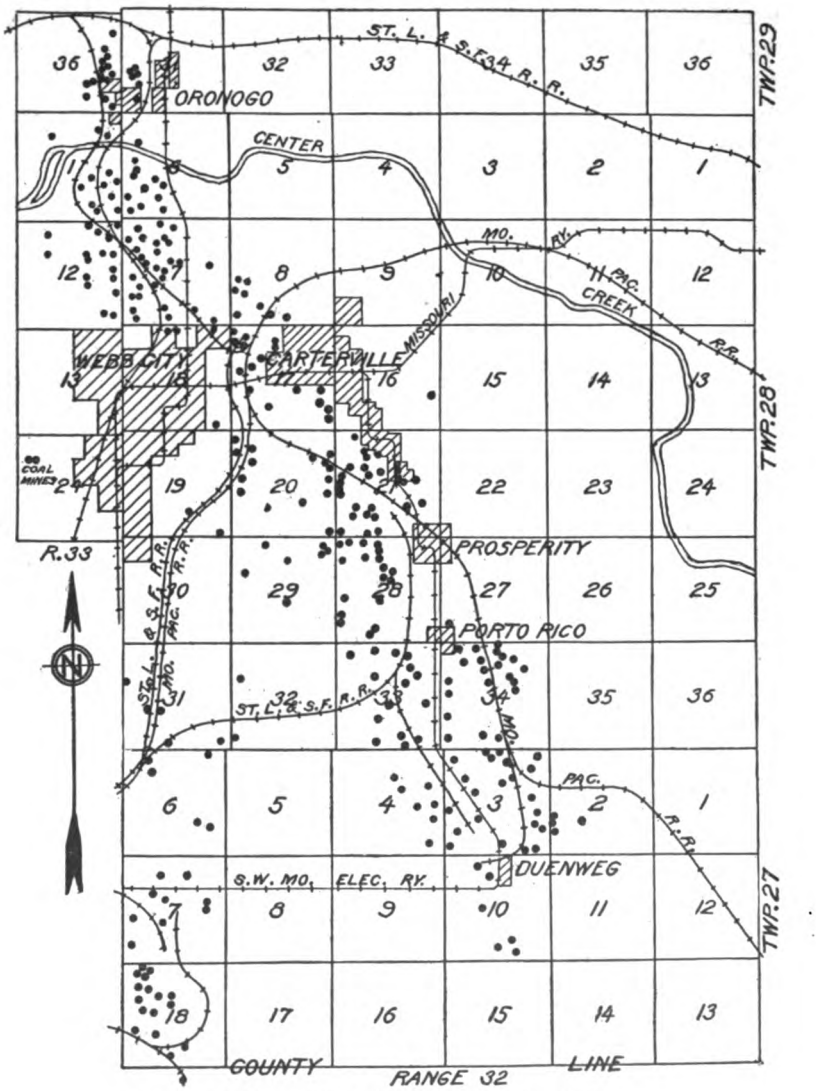

FIGURE 2.—Map of Webb City-Carterville mining district.

directly below the chert) than the sheet-ground deposits, and although the ore is closely associated with chert the ground may or may not consist to a large extent of limestone in the form of bowlders or masses.

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METHODS OF MINING.

The average mine in the sheet-ground district presents the appearance of a huge chamber, lying horizontally, the roof being supported by pillars of various size and frequency. After a shaft has been sunk the ore-bearing bed is attacked, the mining operations developing usually in fan shape. Pillars, usually ore bearing and varying in diameter from 10 to 20 feet, are left at such points as may be thought necessary for the support of the roof. Practice in this respect is rather variable, some pillars being as close together as 20 feet and others as far apart as 100 feet or more. Of late years the usual practice has been to leave pillars 40 to 60 feet apart. As to the interval between pillars, much depends, of course, on the thickness and texture of the ore-bearing bed and the character of the roof. While mining work is carried on in what are termed "drifts," the openings are all connected, the pillars being the only means of distinguishing one

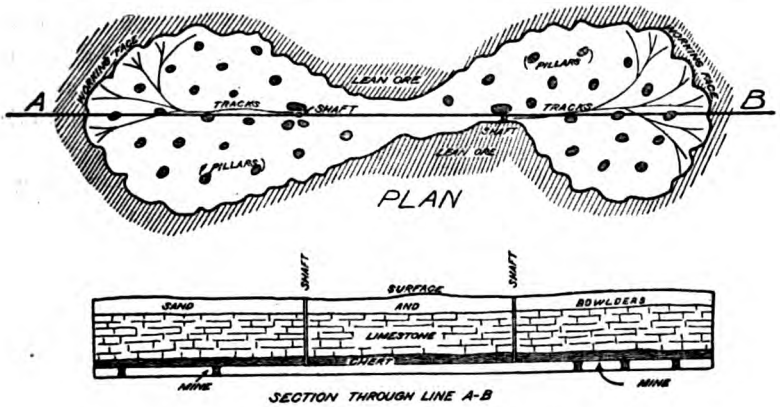

FIGURE 3.—Sketch of sheet-ground mine.

drift from another. The plan and section shown in figure 3 afford some idea of the appearance of a sheet-ground mine.

At the face the ore is drilled, blasted down, shoveled into buckets, and trammed to the shaft. The method of carrying the face depends largely on the thickness of the ore body. Where the ore body is 6 to 18 feet thick, the heading is usually carried vertically. With greater thickness the face may be carried with a heading and a bench, as shown in figure 4. The heading is usually carried 6 to 8 feet high and is kept 15 to 20 feet in advance of the bench.

DRILLING.

Various types of piston drills, working without water and operated by compressed air, are used in the mines. In drilling heading holes, or where the face is carried without a bench, the machine is mounted

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on a column. Tripods are used for bench holes. In a few of the mines power drills in which water passes through the core of the drill to the end of the hole are being tried. Drills are commonly operated by a drill man and a helper. Where the heading is carried without a bench, the holes are usually drilled 8 to 10 feet in length, the lower, or stope, holes usually being slightly longer than the breast and roof holes. Where a bench is carried, the heading holes are drilled 6 to 8 feet in length and those in the bench, called the stope holes, are drilled as deep as 18 feet horizontally.

SQUIBBING.

As has already been mentioned, the flinty chert is extremely hard and tough. In order to introduce sufficient powder into the drill holes to break the rock, it is necessary to enlarge the holes by chambering or springing. Frequently while drilling a hole particles of rock become wedged about the drill, so that it will not work freely; the hole thus becomes "blocked." The remedy for this is to shoot one-half to three sticks of dynamite in the hole. The shooting of blocked holes and the chambering of holes is locally referred to as "squibbing," and this term will be used throughout this report.

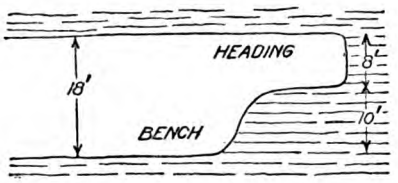

FIGURE 4.—One method of carrying face in thick ore body.

It is the usual practice to drill a round of holes on one shift, squib after the shift leaves the mine, then charge and blast the round at the end of the following day. Thus a round of holes is drilled a day ahead of the final blasting. Holes are squibbed with 1 to 75 sticks of dynamite. As much as three or four boxes of dynamite are sometimes loaded into an 18-foot hole for the final blast. Gelatin and ammonia dynamites of 30 to 40 per cent strength are used. In exceptional cases "80 per cent" gelatin dynamite is used in squibbing.

It is the usual custom in the district to take into the mine sufficient powder for one day's use. This powder is under the charge of a powder man who makes up the primers and loads all holes. However, the drill men are allowed to take what powder they require for squibbing at any time. The powder man loads all holes and the drill men light the fuses as they go off shift. In many of the mines squibbing is also done at noon, as the men leave the face for their dinners. Although the practice of squibbing is regulated as far as possible in some of the mines, as indicated above, it seems to be the general practice to allow squibbing at any and all times when the miners are underground.

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CLEANING DRILL HOLES.

The rock cuttings, especially in dry ground, usually pass freely from the holes. However, before the hole is squibbed or blasted it is necessary to remove from it all the cuttings. For this purpose, or in case the cuttings do not work their way out of the hole freely, a blowpipe is used. This consists of a long pipe about one-half inch in diameter which is connected to the air hose and introduced into the drill hole. When the full force of the compressed air, which may be anywhere from 60 to 100 pounds per square inch, is turned on, the result, especially in dry holes, is a cloud of rock dust that may extend as far as 100 feet away from the drill hole.

SHOVELING.

After the ore is broken down at the face it is shoveled to iron buckets, locally called "cans," holding 1,000 to 1,650 pounds of "dirt," and trammed on a small truck to a switch, called the lay-by, near the face. From the lay-by the trucks are hauled to the shaft by mules. In many cases, however, the shoveler trams the bucket to the shaft.

Most of the ore breaks in pieces small enough for convenient handling with a shovel, but there are many large bowlders that must be broken. Frequently these bowlders can not be broken with a sledge, in which event they are blasted. This practice is known as "bowlder popping."

HOISTING.

Geared hoists, operated either by steam or electricity, are in most common use. There are some first-motion steam hoists. The hoist is placed near the top of the "derrick" (headframe) in such a position that the engineer from his seat at the throttle or controller has an unobstructed view to the bottom of the shaft. Hoisting ropes are usually one-half to five-eighths of an inch in diameter and are made of steel. When a truck with a loaded bucket reaches the shaft station, the "tub hooker" (station tender) attaches the cable to the bail of the bucket by means of a hook. The bucket is then lifted from the truck and hoisted to the top of the derrick. Here, by means of a hook attached to a ring in the bottom of the bucket, the bucket is drawn to one side and quickly dumped, the ore falling on an inclined grizzly spaced at 4 to 5 inches. The bucket, without having been removed from the cable, is immediately returned to the shaft and lowered. On reaching the bottom of the shaft, the empty bucket is immediately detached from the cable and a loaded bucket is made fast.

COMMENTS ON THE METHODS EMPLOYED.

At first glance the methods in use appear crude and inefficient, but as one becomes more familiar with conditions the conclusion is reached that the methods used here are about as efficient as those in

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use in any metal-mining district in the United States. The fact that the working faces in the course of two or three years extend to points far distant from the shaft makes it necessary to sink new shafts from time to time. Obviously, expensive shaft equipment, with ore pockets and skips, would be an extravagance. Although the cost of explosives per ton of rock is high, ranging from 12 to 20 cents per ton of rock broken, tonnage per machine is high and, except in the soft-ground mines, practically no timber is required. The shovelers, who work on a contract price of 6 cents to 8 cents per bucket, handle from 15 to 30 tons of rock per shift. There are exceptional records showing a much higher tonnage than this. The cost of mining and milling ranges from 75 cents to $1.25 per ton.

VENTILATION.

Inasmuch as the investigation of ventilating conditions was confined almost entirely to the sheet-ground mines, the following comments can not be said to refer to the Joplin district in general. In some of the many prospects and smaller mines with only one shaft in which usually only a few men are employed and in many of the timbered mines conditions are reported to be bad. In a large percentage of the sheet-ground mines, however, the ventilation may be termed "good." This applies particularly to those mines having two or more shafts. In that part of the sheet ground in the vicinity of Webb City and Carterville the mines under a large area are connected, and it is possible to walk several miles underground through various properties without returning to the surface.

In these sheet-ground mines having more than one opening, then, it may be said that the air circulation between shafts is usually good. It is at the working faces, especially as they get farther away from a shaft, that the air circulation becomes poor. However, as indicated by the analyses of the air samples given in Table 4, the quality of the air at the faces seems to be affected but little. This is probably due to the usually great size and extent of the mine workings. The effect of vitiation of the air by the breathing of men, the burning of lights, and the combustion of powder, is evidently almost negligible on the relatively large volume of air present. It should be noted also that these mines use practically no timber in the workings. Thus the absorption of oxygen and the production of carbon dioxide by timbers is a factor that need not be considered. As pure atmospheric air contains approximately 20.93 per cent oxygen, 79.04 per cent nitrogen, and 0.03 per cent carbon dioxide, it will be seen from Table 4 that all the air sampled during the course of this investigation was very nearly normal.

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TABLE 4.—*Description and analyses of air samples taken in mines of Joplin district, Missouri, November, 1914.*

Laboratory No.	Name of mine.	Place in mine where sample was taken.	Date taken—1914.	Analysis.				Remarks.
				CO_2.	O_2.	CO.	N.	
				P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	
5637	Schoolhouse	Heading 13	Nov. 16	0.26	20.79	0	78.95	Taken 2 minutes after squibbing 9-foot hole with 2 sticks of 35 per cent gelatin dynamite.
5638	do	do	do	.11	20.85	0	79.04	Duplicate of No. 5637.
5639	Little Princess	West slope, No. 2 mill shaft	Nov. 17	.21	20.74	0	79.05	After squibbing 14-foot hole with 15 sticks 35 per cent ammonia dynamite.
5640	do	do	do	.16	20.79	0	79.05	Duplicate of No. 5639.
5641	Ice plant	Heading 7	do	.11	20.83	0	79.06	After squibbing hole with 2 sticks of 27 per cent ammonia dynamite.
5642	do	do	do	.08	20.88	0	79.04	Duplicate of No. 5641.
5635	Longacre and Chapman.	Bottom main shaft	Nov. 16	.07	20.92	0	79.01	Main return air.
5636	do	do	do	.07	20.92	0	79.01	Duplicate of No. 5635.
5630	Davey No. 3	Drift 350 feet south of No. 7 shaft	Nov. 9	.07	20.91	0	79.02	Main return air.
5629	do	do	do	.07	20.92	0	79.01	Duplicate of No. 5630.
5627	do	Face of No. 10 drift	do	.10	20.81	0	79.09	
5628	do	do	do	.07	20.90	0	79.03	Duplicate of No. 5627.
5631	Coahuilla	Station, main shaft	Nov. 10	.07	20.84	0	79.09	Main return air.
5632	do	do	do	.10	20.84	0	79.06	Duplicate of No. 5631.
5626	Electrical	Heading southeast of main shaft	Nov. 19	.11	20.86	0	79.03	One-half hour after squibbing 2 holes with 36 sticks 80 per cent gelatin dynamite.
5625	do	do	do	.07	20.86	0	79.07	Duplicate of No. 5626.
5623	Oronogo Circle	Heading at south end of workings	Nov. 18	.11	20.88	0	79.01	After squibbing 11-foot hole with 3 sticks 35 per cent gelatin dynamite.
5624	do	do	do	.10	20.85	0	79.05	Duplicate of No. 5623.
5622	Florine	Heading south of shaft	do	.10	20.81	0	79.09	After squibbing hole with 2 sticks 35 per cent ammonia dynamite.
5621	do	do	do	.21	20.69	0	79.10	Duplicate of No. 5622.
5633	Wilson	Heading 300 feet east of main shaft	Nov. 11	.14	20.75	0	79.11	After squibbing hole with 3 sticks 33 per cent gelatine dynamite.
5634	do	do	do	.11	20.93	0	78.96	Duplicate of No. 5633.
5680	Hornbrook	Second south face	Nov. 25	.07	20.78	0	79.15	5 minutes after shooting two 7-foot holes using 20 sticks of $\frac{7}{8}$-inch 40 per cent gelatin dynamite.
5679	do	do	do	.11	20.74	0	79.15	Duplicate of No. 5680.

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TEMPERATURE.

The temperatures at the working faces of the mines examined ranged from 58 to 63° F., the corresponding relative humidity being 70 to 100 per cent. Surface temperatures ranged from 30 to 50° F., the relative humidity averaging 50 per cent. Although the temperatures underground were good, it must be remembered that the observations were made during a period of the year in which climatic conditions are most nearly ideal. In the hot months of summer conditions are probably more severe.

MINE WATER.

Records of water pumped from the various mines examined ranged from a few gallons up to as high as 1,500 gallons per minute. In places one pumping plant handles the water from several mines. The amount of water made by a mine, however, is no indication of the amount of rock dust that may be produced, for the working faces may be at a slightly higher elevation than the principal source of water, and therefore may be rather dry. Mines making as much as 1,000 gallons of water per minute were found to have dusty working faces, and those producing much smaller amounts showed relatively less dust at the faces.

ROCK DUST IN THE MINES.

CAUSES OF DUST.

As indicated in another part of this report, there was little or no rock dust to be found in mines other than those in the sheet ground. For this reason the investigation of rock-dust conditions was confined almost entirely to sheet-ground mines. The chief causes of rock dust in these mines are the blowing of dry holes, squibbing, and bowlder popping. Among other causes may be mentioned shoveling, drilling without water, pillar and roof trimming, tramming, and the dumping of the bucket on the surface.

DUST CAUSED BY THE BLOWING OF DRY HOLES.

In some of the mines, where much water is made at the face, the drill cuttings become dampened and little or no dust is produced. Where the face is comparatively dry, however, as in most of the sheet-ground mines, the blowing out of the drill holes produces great quantities of dust. This dust does not settle at once, but usually remains in suspension for considerable lengths of time. The practice of blowing holes dry is especially severe on the man who does the blowing, for he is forced to breathe air containing comparatively large particles of dust. This practice is entirely unnecessary, and its elimination will do much toward keeping the mine air clear of dust.

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DUST CAUSED BY SQUIBBING AND BOWLDER POPPING.

When a shot explodes, whether it be in a drill hole or on a bowlder, the concussion, followed by the violent vibration of the air, sets in motion the particles of dust that fill every available space about the face, and even at some distance from it. The popping of bowlders when the men are in the mine is entirely unnecessary, and should be prohibited. Although it seems impossible entirely to eliminate squibbing while the shift is underground, there is no question that this practice is too common, and that it can be almost entirely eliminated. The only time when there is a valid excuse for squibbing when the shift is at work is when the drill refuses to work in a hole that is well along toward completion. Obviously, the abandonment of the hole would result in a great loss of time. It seems to be the common practice, instead of trying to overcome this difficulty by lining up the drill machines, to immediately withdraw the drill and resort to powder to remove the obstruction. In most cases the difficulty could be overcome by a proper alignment of the drill.

Indiscriminate and frequent squibbing and bowlder popping seem to be the rule in many mines. This practice not only produces rock dust, but has a tendency to increase the cost of powder, to increase the production of poisonous powder gases at the face, and to increase the element of danger to the men from walking into a blast, from shaking loose slabs of rock, or from firing such shots with dynamite lying about the face.

DUST MADE BY DRILLING.

Although a large quantity of rock is ground to small size by rock drills, the act of drilling does not tend to set in motion a great deal of dust. Exceptions to this may be in dry heading holes. However, the dust made by drilling without water is ever ready to be set in motion through squibbing, bowlder popping, or the blowing of dry holes. Various types of drills in which water is caused to pass through the core of the drill steel have been tried with success in a few of the mines. Although it might work a hardship on many of the operators if they were compelled to change their equipment from the drills working without water (now commonly in use) to those using water, the tendency should be, in obtaining new equipment, to procure some type of water drill. On the other hand, it is possible to equip the drills now in common use with a water spray directed into the drill hole and make them effective in preventing dust from drilling.

DUST PRODUCED BY SHOVELING AND OTHER OPERATIONS.

A certain amount of dust is made in shoveling, but the quantity may be either great or small depending on whether the dirt is wet or dry. It was noted that the shovelers prefer to work standing in a

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pool of water, if such a pool is available, for the reason that the water causes the dirt to run more freely. Although under such conditions the dust may be somewhat abated, a thorough wetting of the broken rock at the face, by means of a water hose, would be more effective.

The dust produced by other operations, such as tramming, pillar-and-roof trimming, and the dumping of the bucket on the surface need not be discussed at length. Dust from these causes will doubtless be abated as a result of the free use of water at the working faces.

HOW THE DUST SAMPLES WERE TAKEN.

The device used for sampling the dust is shown in Plates I and II. Plate I shows the apparatus assembled and Plate II shows the nose clip, mouthpiece, valves, and connections. The device consists essentially of the following parts:

A glass bulb or container for the filtering medium. This bulb is partly filled with granulated sugar, which has been found in tests made in South Africa and in tests by the Bureau of Mines, to be superior to any other medium as a dust filter. The granulated sugar is prevented from passing into the sampling device by means of a perforated glass plate inserted in the bottom of the glass bulb.

That part of the oxygen-breathing apparatus known as the mouthpiece, with inhalation and exhalation tubes attached. The mouthpiece may be held securely in position, when the device is in use, by means of a cap to which straps are attached. It is not necessary, however, to use a cap when one becomes familiar with the device.

A nose clip to prevent air from passing in or out of the nostrils.

What is known as a Draeger liter bag, having a capacity of 35 liters.

The purpose of this device is to determine the weight of rock dust in a given volume of air. In order to collect a sample, the apparatus is adjusted in the mouth with a dust bulb and liter bag attached. The nose clip is then placed on the nose and the person taking the sample breathes naturally. When air is inhaled the valve in the inhalation tube opens, allowing the air to pass to the lungs; at the same time the valve in the exhalation tube closes, making it impossible to draw air from the liter bag. When air is exhaled from the lungs the valve in the inhalation tube closes and that in the exhalation tube opens. In taking a sample, then, the air passes through the bulb (where the dust is intercepted by the sugar) into the lungs, and thence through the exhalation tube to the liter bag, where it is measured. Ordinarily, sufficient accuracy may be secured by inhaling and breathing out a total of 35 liters of air. However, if the place in which the sample is taken is only slightly dusty, the bag may be filled a second time, thus making a total of 70 liters of air for the sample.

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APPARATUS FOR DETERMINING ROCK DUST IN MINE AIR.

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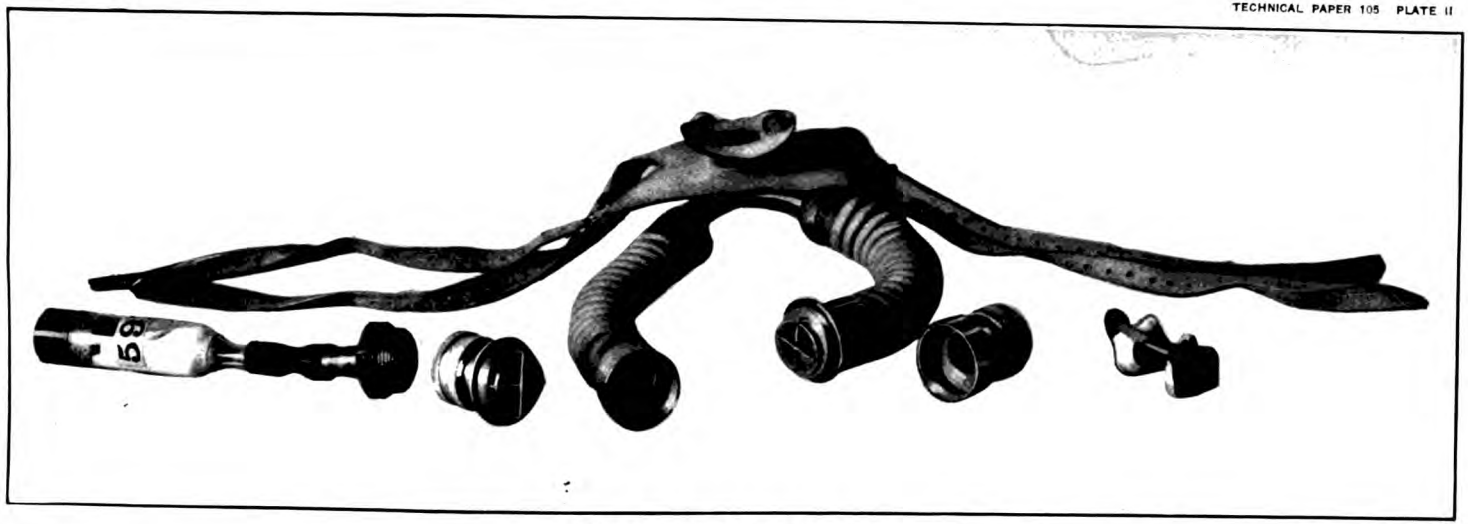

DETAILS OF DUST-SAMPLING DEVICE.

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In order to determine the amount of dust collected, the contents of the bulb are washed out into a weighed Gooch crucible and dried at 105° F. After successive washings with water, to dissolve and remove all of the sugar, the crucible is again dried at 105° and weighed. The increase in weight represents the weight of rock dust in the sample.

ACCURACY OF SAMPLING DEVICE.

The air exhaled from the lungs occupies about one-fiftieth less volume than the air that is inhaled. This is not an appreciable error and may be corrected easily. The fact that a large volume of air, 35 liters—or 70 liters, if desired—is taken at one sampling, makes for accuracy. Although the liter bag is not elastic, there may be a small source of error in determining at just what point it should be considered to be full of air. This source of error, however, may be reduced to a minimum by practice in using the device. As to the velocity of the air entering the sugar bulb and the frequency of the inhalations, it may be pointed out that in using this device it is possible practically to imitate the breathing of a miner at work. It is important to note, also, that a sample may be taken in about two minutes.

The liter bag may be tested for leaks by filling it with air and allowing it to remain for one-half hour or more. A leak will be indicated by loss of air. The tubes leading to the mouthpiece may be tested for leaks by coating them with soap lather, holding the palms of the hands over the ends of the tubes and blowing through the mouthpiece. If there are any leaks, bubbles will appear at the leaky points.

RESULTS OF DUST SAMPLING.

A total of 39 dust samples were taken. These were obtained under the various conditions that commonly arise during the progress of mine work. The data in Table 5 afford an idea of the quantity of dust produced during the various details of the mining operations. It should be borne in mind that nearly all drill holes bored in these mines are practically horizontal. The results show that there is a variation in the volume of dust produced in different mines by the same operation. For instance, in a certain mine, more dust may be produced by the blowing of the hole, or by drilling, than in other mines. This variation is due chiefly to the fact that the amount of water made at the faces is variable. Many of the faces are comparatively dry.

Especial attention is directed to the fact that dust samples were collected in all cases where men were performing their work, and that the test bulb in every case was held close to the face of the miner at work and not near the source of the dust.

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In the mines of the Joplin district, unlike those in which work is done on various levels, the dust produced permeates all the workings. The most dust, however, is found at the working faces. For example, along a continuous working face, say, 200 feet across, there may be working at more or less regular intervals 5 or 6 drills and 10 to 15 shovelers. During a large part of the day dust is being raised by drilling, squibbing, bowlder popping, blowing dry holes, and shoveling. The dust set in motion passes in a cloud across the whole 200 feet at a rate of speed depending on the air current. In most cases the current at the face is sluggish; sometimes the air is practically stagnant. Thus all of these men, who constitute a large majority of the men underground, are subjected to a dusty atmosphere during the entire shift. For a few minutes there may be more dust at one point than at another, but in general the whole working face is dusty. In dusty metal mines where work is conducted on various levels, usually a comparatively small proportion of the miners underground are subjected to a dusty atmosphere.

Although any attempt to figure the quantity of dust breathed by a miner during eight hours under the above conditions would be subject to a large error, a rough approximation may be made. The average weight of dust collected in the sugar tube by breathing naturally for two minutes was slightly more than 1 milligram. Figuring on 1 milligram, this would indicate that a miner would take into his air passages a total of 240 milligrams in eight hours. Of course, it can not be stated how much of this dust would be held in the air passages and how much would reach the lungs.

TABLE 5.—*Analyses of 39 samples of siliceous rock dust taken in sheet-ground mines of the Joplin district, Missouri, in November, 1914.*[a]

Sample No.	Laboratory No.	Name of mine.	Work progressing.	Weight of dust per 100 liters of air.
				Mg.
202	20453	Ice Plant	Drilling heading hole, dry	6.57
203	20454	do	After squibbing	4.86
209	20455	do	do	6.00
210	20456	Gopher	Shoveling	3.71
[b]593	20457	do	do	4.57
587	20488	do	do	4.86
211	20458	Little Princess	Drilling and shoveling 10 feet away	4.00
[b]212	20459	do	do	5.14
212 A	20460	Florine	Drilling and shoveling	5.14
[b]216	20461	do	do	5.71
215	20462	Oronogo Circle	Drilling, dry	3.71
222	20463	Century	Shoveling (5 men) 5 to 15 feet away	4.29
[b]564	20464	do	do	3.71
419	20465	Davey No. 3	Drilling heading hole, dry	6.86
420	20466	do	do	5.14
421	20467	do	Blowing hole, damp	4.29
424	20470	do	Drilling bench hole, damp	.57
426	20472	do	After squibbing	4.29
423	20469	Coahuilla	Drilling heading hole, dry	4.00
574	20483	do	Shoveling	3.60
576	20485	do	do	1.14

[a] All holes drilled horizontally. All samples taken close to nostrils of miner.
[b] Duplicate of preceding sample.

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TABLE 5.—*Analyses of 39 samples of siliceous rock dust taken in sheet-ground mines of the Joplin district, Missouri, in November, 1914*—Continued.

Sample No.	Laboratory No.	Name of mine.	Work progressing.	Weight of dust per 100 liters of air.
				Mg.
425	20471	Wilson	Shoveling and roof trimming	2.29
573	20482	do	Shoveling	.57
571	20480	do	Drilling heading hole, dry	3.60
572	20481	do	Blowing hole, dry	7.71
563	20473	Schoolhouse	5 minutes after blowing hole, dry	3.14
567	20476	do	After squibbing	7.16
[a]567A	20477	do	do	5.71
566	20475	Wingfield	Drilling heading hole, dry	3.14
[b]575	20484	do	do	3.14
569	20478	Bertha A	do	6.29
570	20479	do	do	6.00
580	20486	Otis	Drilling bench hole, damp	2.86
578	20487	do	Drilling heading hole, dry	6.00
590	20489	A. W. C. No. 1	Drilling and shoveling	6.57
596	20490	do	Shoveling	3.60
591	20491	Little Dorothy	Drilling in heading, dry	4.57
592	20492	Electrical	None; ½ hour after squibbing 5 holes	4.00
[b]583	20493	do	do	4.86

[a] Taken 3 minutes after sample 567 was taken.
[b] Duplicate of preceding sample.

SIZING AND CHEMICAL TESTS ON DRILL CUTTINGS.

Samples of drill cuttings were procured in nearly all cases where dust samples were taken during the drilling of holes. The amount of siliceous residue in the whole sample was determined; then sizing tests were made, after which the siliceous residue in that part of the sample passing through a 240-mesh sieve was determined.

The results of the chemical examination of the drill cuttings are shown in Table 6. Evidently the sheet-ground mines produce a dust that is essentially siliceous.

Table 7 shows the results of the sizing tests. Attention is directed to the variation in the percentage of drill cuttings passing through a 240-mesh sieve. This indicates a variation in the dust-producing tendency of the chert in different mines. The sizes of the openings in the screens used in the sizing tests were as follows:

Standard screens used for sizing tests.

Mesh of sieve.	Size of opening.	
	Inches.	*Mm.*
10	0.065	1.651
20	.0328	.833
35	.0164	.417
65	.0082	.208
100	.0058	.147
150	.0041	.104
200	.0029	.074
240	.0026	.066

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For purposes of comparison the following illustration will serve to indicate how the results in Tables 5, 6, and 7 may be correlated. Take sample No. 211 (disregard the laboratory number) appearing on the first line of Tables 6 and 7. The results stated, of course, refer to the same sample of drill cuttings. Reference to Table 5 on the seventh line shows that sample No. 211 was taken in the Little Princess mine, and that the rock dust sample contained 4 milligrams of dust per 100 liters of air. Tables 6 and 7 follow.

TABLE 6.—*Results of chemical examination of drill cuttings.*

Laboratory No.	Sample No.	Siliceous residue.		Relative amount of carbonate as indicated by effervescence with hydrochloric acid.	Relative amount of sulphide present as indicated by action of nitric acid.
		Average sample.	Through 240 mesh.		
		Per cent.	*Per cent.*		
20788	211	95.3	96.8	Medium	Nil.
20789	202	89.4	80.1	do	Do.
20790	215	70.5	61.3	Much	Much sulphide.
20791	422, 423	89.8	85.6	do	Little sulphide.
20792	424	91.7	93.2	Little	Nil.
20793	426	90.2	93.6	do	Much sulphide.
20794	566, 575	90.8	88.8	Medium	Do.
20795	567	94.9	95.3	do	Nil.
20796	569	95.2	97.0	Little	Do.
20797	570	94.9	96.2	Medium	Do.
20798	571, 572	86.8	83.6	Little	Little sulphide.
20799	576, 574	78.8	75.9	do	Do.
20800	580	91.2	90.6	do	Nil.
20801	590	94.8	94.6	do	Little sulphide.
20802	591	90.8	93.7	do	Nil.

TABLE 7.—*Results of sizing tests on drill cuttings.*

Laboratory No.	Sample No.	On 10 mesh.	On 20 mesh.	On 35 mesh.	On 65 mesh.	On 100 mesh.	On 150 mesh.	On 200 mesh.	On 240 mesh.	Through 240 mesh.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
20788	211	11.2	9.3	14.9	40.5	5.2	6.7	4.9	3.4	3.9
20789	202	12.0	12.5	17.5	15.3	19.1	4.5	7.2	2.2	9.7
20790	215	12.3	5.5	12.4	17.9	11.0	9.0	9.2	7.5	15.2
20791	422, 423	5.9	5.6	12.8	21.7	12.2	9.6	6.5	4.6	21.1
20792	424	34.6	15.8	16.0	11.1	5.8	3.5	2.5	.5	10.2
20793	426	20.4	12.2	14.4	14.0	8.8	7.5	4.0	.1	18.6
20794	566, 575	10.8	7.3	16.7	19.8	10.3	7.9	8.0	.1	19.1
20795	567	57.2	14.0	10.9	6.6	3.0	1.8	1.0	.1	5.4
20796	569	16.7	21.3	36.5	13.1	3.4	1.9	1.0	.1	6.0
20797	570	3.9	3.6	13.0	26.8	16.5	8.2	5.9	.4	21.7
20798	571, 572	7.3	6.5	10.4	15.1	10.7	9.1	7.0	.2	33.7
20799	576, 574	11.4	4.5	10.1	19.4	11.1	7.6	5.2	.6	30.1
20800	580	16.5	12.6	18.0	14.6	9.3	5.8	3.9	.5	18.8
20801	590	12.1	10.0	15.1	17.2	10.5	6.0	3.6	.7	24.8
20802	591	5.2	5.3	9.9	20.6	11.5	9.3	9.2	2.5	26.5

MICROSCOPIC EXAMINATION OF DUST PARTICLES.

Portions of the samples that passed the 240-mesh screen in the sizing tests were examined under the microscope by Reinhardt Thiessen, who prepared the accompanying photomicrographs (Pls. III to V).

About 0.5 milligram of each sample examined was mixed or stirred into a drop of cedar oil, placed on a glass slide, and observed under the

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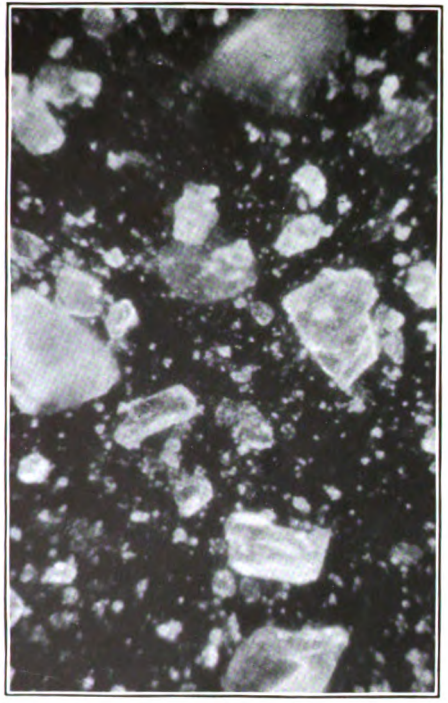
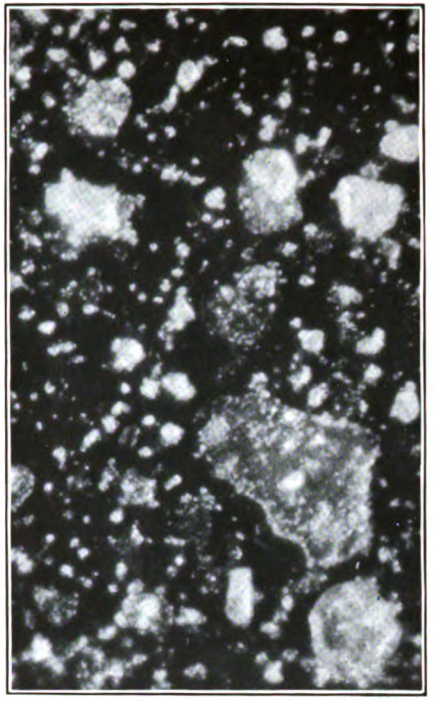


A. ROCK DUST FROM SAMPLE 215, PARTICLES MAGNIFIED 250 DIAMETERS.



B. ROCK DUST FROM SAMPLE 215, PARTICLES MAGNIFIED 500 DIAMETERS.

C. ROCK DUST FROM SAMPLE 424, PARTICLES MAGNIFIED 250 DIAMETERS.

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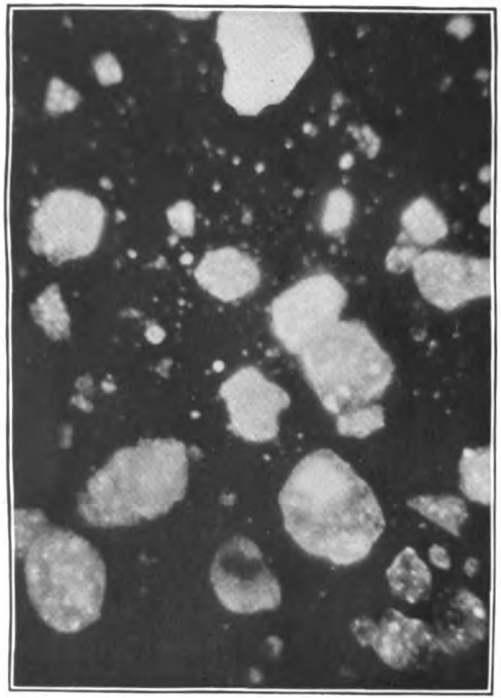
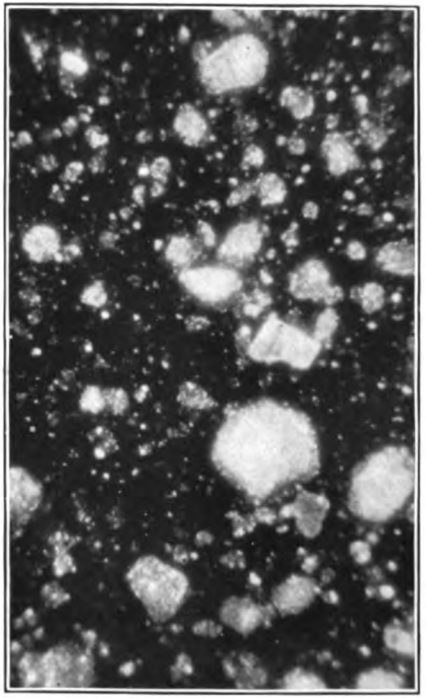


A. ROUNDED AND POLYHEDRAL PARTICLES FROM SAMPLE 424, MAGNIFICATION 200 DIAMETERS.

B. PARTICLES FROM SAMPLE 566, MAGNIFICATION 500 DIAMETERS.



C. ROCK DUST FROM SAMPLE 591, PARTICLES MAGNIFIED 250 DIAMETERS.

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microscope. The results of Dr. Thiessen's observations are given herewith:

GENERAL DESCRIPTION.

In size the dust particles varied from those averaging about 90 microns [a] down to particles that were invisible under the ordinary microscope, one-tenth micron. Some of the samples were made up chiefly of the smaller sizes, whereas others consisted mostly of the larger and intermediate sizes.

Although the larger sizes measured approximately 100 to 60 microns, there were some longer and narrower knifelike or needle-shaped particles. The smallest dimension measureable by the ordinary microscope is one-fourth to one-half micron. The smallest particle visible was about 20 millimicrons, or twenty one-thousandths of a micron.

PHYSICAL CHARACTER OF PARTICLES.

In the main two kinds of particles are visible; one having a milk-white or porcelain-like look, and the other being more glassy. The milky particles are generally thin, sharp edged, and irregular, often knifelike or spearpoint-like in shape. The glassy particles are usually roughly polyhedral or spheroidal, although some are sharp edged or pointed. Of the other particles visible, some are perfect crystals, evidently calcite; others are sphalerite, galena, and pyrite. The particles are of almost every possible shape and form. The milk-white, sharp-edged particles are usually thin and scalelike; comparatively few are rounded or polyhedral. The glassy particles, on the other hand, are usually rounded or tetrahedral.

SUSPENSION OF PARTICLES IN THE AIR.

A large proportion of the dust particles are less than 1 micron in diameter. How long such small particles will remain suspended in dry still air can be roughly determined fron Stokes's law, the formula for which is:

$$V = \frac{2r^2(s-s')g}{9z}$$

V=the velocity of fall in seconds per centimeter;
r=the radius of the particle in suspension;
s=the specific gravity of the particle;
s'=the specific gravity of the medium in which it is suspended;
g=the gravity constant;
z=the viscosity coefficient of the suspending medium.

If it be assumed that a certain round particle of quartz (specific gravity=2.62) is 1 micron (or 0.0001 centimeter) in diameter, and

[a] 1 micron=one one-thousandth millimeter.

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that the air (temperature 60° F.) is free from moisture, substituting values gives:

$$V=\frac{2\times 0.00005^2(2.62-0.0012)980}{9\times\frac{1970}{107}}=\frac{2\times 0.0000000025\times(2.62\times 980)}{9\times 0.0001970}=0.0072 \text{ centimeter}$$

per second=0.432 centimeter per minute=25.92 centimeters per hour=620.08 centimeters or 6.2 meters (20.34 feet) per day.

Supposing that a particle is 0.2 micron in diameter, then

$$V=\frac{2\times 0.000001^2\times 2.62\times 980}{9\times 0.000197}=0.000028 \text{ centimeter or } 0.00028 \text{ millimeter per second}=$$

0.0168 millimeter per minute=1 millimeter per hour=24 millimeters (0.94 inch per day.

Although these theoretical calculations are of interest, it is obvious that in any attempt to determine the length of time dust particles will remain in suspension in mine air proper consideration must be given to air currents and to humidity.

DESCRIPTION AND DISCUSSION OF PHOTOMICROGRAPHS.

In the following descriptions and discussions of the photomicrographs shown in Plates III to V, the sample numbers used in Tables 5, 6, and 7 are retained.

Sample 215 (*Lab. No. 20790*).—The gradation in size is gradual. The largest particles measure about 85 microns (0.085 mm.). Sharp, angular, and irregular particles predominate.

In Plate III, *A*, magnification 250 diameters, the particle at the right is approximately 85 microns long and 48 microns wide. The smaller particles, represented by spots, are less than 1 micron. In Plate III, *B*, magnification of 500 diameters, the largest particle is approximately 56 microns in diameter.

Sample 424 (*Lab. No. 20792*).—This sample has a large proportion of the coarser particles and relatively few very small particles. Both the milky white, irregular, sharp-edged particles and the glassy irregular spherical particles are shown.

Plate III, *C*, magnification 250 diameters, shows the abundance of the large particles, and some of the milky white, sharp-edged ones, which are very thin and spadelike.

Plate IV, *A*, magnification 200 diameters, shows the rounded and polyhedral particles.

Sample 566 (*Lab. No. 20794*).—This sample is characterized by rather sharp, angular particles, with a large number of particles ranging from medium size down to invisible; that is, from 25 microns in diameter to about 1 micron, in which the milky white or porcelain-like are the most abundant.

The porcelain-like particles vary widely in form. Besides the sharp knife-like or angular particles, rhomboidal, tetrahedral, and even globular forms, not entirely restricted to this sample, yet more common than in others are present.

In Plate IV, *B*, magnification 500 diameters, the clear rhombohedral particle in the lower right-hand corner is about 24 microns long, 20 microns wide, and 10 microns thick. The thin plate-like particle in the lower left-hand corner almost clear on the left-hand half, but containing millions of minute inclusions in the right half, is about 36 microns long and wide but probably less than 0.5 micron thick. The sharp-pointed particle in the middle has a knife-like edge on the left and is rather thick on the right.

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Sample 567 (*Lab. No. 20795*).—The gradation ranges from the larger particles down to those that are invisible. The smaller ultramicroscopic particles are more abundant than in any of the other photomicrographs shown. There are also more sharp-edged particles, with even sharper edges than in any other sample. In the other samples the scalelike, sharp-edged particles are confined to the larger and medium sizes, but in these samples grade into the invisible. Two kinds of particles predominate, the milky white, which comprise the bulk of the larger sizes but are not confined to them, and the glassy particles, which are mostly rounded, although many are sharp-edged. The milky white particles are almost always thin, bladelike, leaf-like, pointed, and some even needle-like.

In Plate V, *A*, the finer particles were removed in order to show the larger ones which are angular and sharp-edged. All of the particles are porcelain-like. The length of the long slender particle is approximately 230 microns, and its least breadth is little more than 8 microns.

Sample 576 (*Lab. No. 20799*).—In this sample there is an almost complete absence of the milky-white material, the particles being glassy. (See Pl. V, *B*.) There are comparatively few large particles, the gradation being uniform.

Plate V, *C*, magnification 400 diameters, shows one of the largest particles that could be found in the preparation. Its largest dimension is about 80 microns. This photograph shows the relatively large proportion of the finest dust particles.

Sample 591 (*Lab. No. 20802*).—This sample is composed largely of rather spheroidal or roughly polyhedral particles varying from the largest to the smallest visible. There are few milky-white particles present and also few sharp or knifelike particles.

Plate IV, *C* (No. 591), shows the general distribution and comparative sizes. The largest one is approximately 60 microns in diameter. The spherical or oval form is also shown.

DISCUSSION OF RESULTS OF DUST SAMPLING.

The weight of rock dust contained in mine air in South Africa, Australia, and England[a] was found in some cases to be considerably higher than those set forth in Table 5. Haldane[b] states, as regards metal mines in Cornwall, that in the air of an "end" or "rise," with a rock drill at work boring dry holes, the air commonly contains 5 to 10 milligrams of dust per 10 liters.

As pointed out previously, the area of the connected open ground (on the same level) in the mines of the Joplin district is far greater than in the average metal mine. Obviously, the amount of dust in a given volume of air would be much greater in a confined area, such as the face of a drift, in a raise, or in a stope, than in a more open space.

Moreover, in taking the dust samples in the Joplin district the sampling bulb was invariably held near the head of the miner at work, so that the results obtained are not comparable with sampling closer to the source of the dust. Obviously, there will be more dust in the air near the source than at points 5 to 10 feet distant. It is conceivable that larger dust particles may be collected close to the source of the dust, and that these larger particles will greatly outweigh the smaller particles that would be found in suspension farther away.

[a] Haldane, J. S., Martin, J. S., and Thomas, R. A., Report to the Secretary of State for the Home Department on the health of Cornish miners. 1904.

[b] Haldane, J. S., The investigation of mine air, 1908, pp. 121–122.

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The records of the countries referred to, in extreme cases, indicated as high as ten times more dust (in comparatively confined places) than was found in the Joplin mines. It is doubtless true that there will be more dust produced per volume of air in drifts, raises, and stopes than is produced in the Joplin mines. The writer does not believe, however, for the reason stated (regarding the point at which the samples were collected), that the amount would be five or ten times greater.

The following conclusions may be set down regarding the production and prevalence of rock dust in the Joplin sheet-ground mines:

1. Rock dust is produced by the blowing of dry holes, squibbing, bowlder popping, drilling without water, shoveling, tramming, roof and pillar trimming, and the dumping of the bucket on the surface.

2. The mine workings constitute practically one large open chamber, which allows the dust to disseminate more quickly than would be possible in more restricted workings.

3. Although the amount of dust in the air is not comparatively large, practically every man underground is exposed to a dusty atmosphere during his entire shift.

4. Most holes are drilled nearly horizontally. Such holes produce less dust than those drilled upward.

5. The rock-dust particles are made up almost entirely of flinty chert which breaks with splintery and knifelike edges.

MEASURES NOW IN USE FOR THE ABATEMENT OF ROCK DUST.

About two years ago the three mine inspectors of the Joplin district began a campaign for the abatement of rock dust. Although a few of the operators adopted recommendations for spraying the working faces and wetting dry holes, it was found to be difficult to bring about a general adoption of precautionary measures. Even in cases where the operator piped water to the face, the miner himself showed little tendency to use the water thus provided. The mine inspectors have been insistent in their efforts, with the result that some of the mines are now in fair condition as far as the prevalence of rock dust is concerned. Many of the mines have either separate water lines to the face or provision for introducing water into the air lines. Many of the operators also are making efforts, through their ground bosses, to cause the miners to use water and to refrain from excessive squibbing and the blowing of dry holes. However, it may be said in general that these efforts have not gone a great way toward eliminating rock dust in the mines.

RECOMMENDATIONS FOR THE ABATEMENT OF ROCK DUST.

As to the most efficient method of allaying the dust, experience in the sheet-ground district indicates that the choice lies between two methods:

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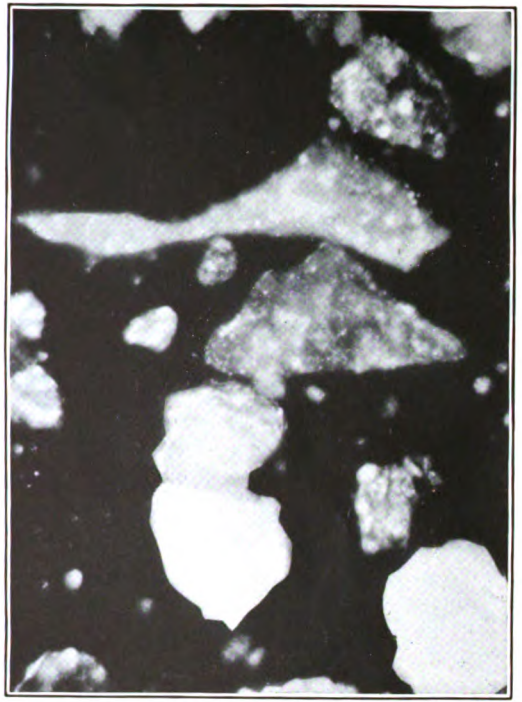
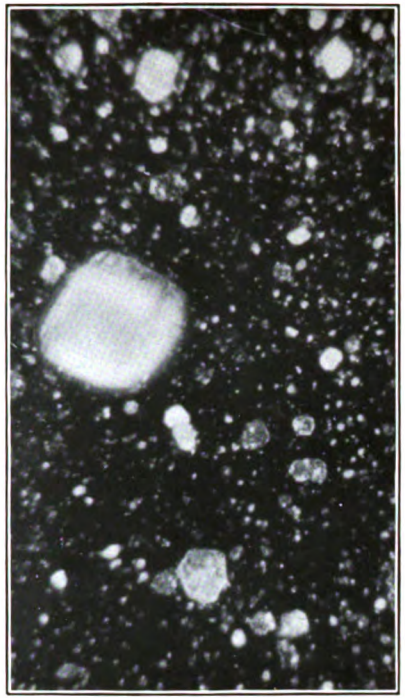
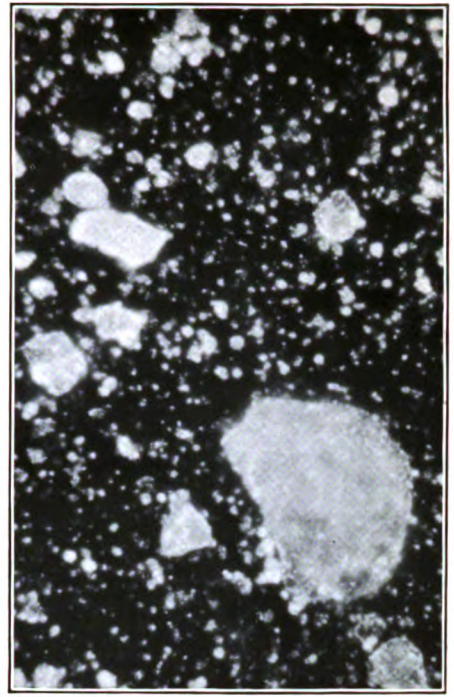


A. LARGER PARTICLES IN ROCK DUST FROM SAMPLE 567, MAGNIFICATION 250 DIAMETERS.



B. ROCK DUST FROM SAMPLE 576, MAGNIFICATION 250 DIAMETERS.



C. ROCK DUST FROM SAMPLE 576, SHOWING RELATIVELY LARGE PROPORTION OF FINER PARTICLES, MAGNIFICATION 400 DIAMETERS.

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(*a*) The use of some type of drill that provides for water passing through the core of the drill steel into the drill hole.

(*b*) The spraying of the drill holes, faces, and broken rock by means of a hose to which a nozzle is attached.

In either method a separate water line should be laid to every working face. As none of the mines is yet equipped entirely with water drills, no opportunity has been offered for determining which method is the better. Moreover, a personal element enters into the question.

With the water drill the dust produced by drilling is converted into slime or mud before it passes from the drill hole. However, a great amount of dust is produced by blasting, and this dust may be easily set in motion by shoveling, squibbing, or bowlder popping. In order to settle the dust so produced the miner must uncouple the water hose from the drill and spray the face and broken rock from time to time. This duty he is likely to shirk. Where drills are operated without water but a hose is used for wetting the drill holes, face, and broken rock, the dust is not quite so effectively stopped in the drill holes. On the other hand, it is less trouble for the miner to turn his spray around to the face or broken rock. In either method the attitude of the miners toward the use of water and the ability of the ground boss to have his orders carried out are important factors.

The following recommendations are offered for the abatement of rock dust:

1. Provide a water supply for every working face by the laying of a separate water line.

2. Where drills are operated without water, attach to the hose leading to the face a 5 or 6 foot length of pipe with a nozzle from one-eighth to one-fourth inch in diameter. Make and enforce such regulations as will insure the use of this water spray for the purpose of wetting drill holes, the face, and the broken rock about the face. For the purpose of washing drill cuttings from drill holes, this hose may be attached to the long pipes now in use for blowing out drill holes.

3. Where there is in use some type of drilling machine that provides for water passing through the core of the drill steel into the drill holes, make and enforce regulations that will insure the spraying of the face and broken rock for short periods at such times as the drill may not be in operation. For this purpose the water hose must be uncoupled from the drilling machine unless a tee and a short length of hose are used.

4. Make and strictly enforce rules against squibbing and bowlder popping while the shift is underground, and against the blowing of dry holes at all times.

5. Improve ventilation by the opening of new shafts whenever practicable.

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SANITATION AT THE MINES, AND OTHER CONSIDERATIONS.

By A. J. Lanza.

INTRODUCTION.

The regulation of sanitary conditions in the mines comes under the jurisdiction of the State mine inspectors. Although these inspectors are directed to make proper sanitation one of their duties, there are (December, 1914) no laws covering the subject. Consequently it has been largely on their own initiative and with difficulty that they have been able to institute reforms aimed at safeguarding the health of miners. Cooperation between mine operators and inspectors has accomplished much good and still offers the best guaranty for the future.

TOILET SYSTEMS.

There is no established toilet system underground in the Joplin district. Many of the mines are small, employing 25 or 30 men and less, and the necessity for the toilet systems seen in large mines does not exist. As in other mining districts, there is a strict rule against ground pollution in the mines, a rule that, as elsewhere, is not infrequently broken. In some of the mines visited there was much evidence of this abuse, and in spite of efforts of operators and ground bosses, there is always, from time to time, infringement of the rule. It does not seem at present that there is any pressing need of establishing toilet systems underground, though they might prove useful in some of the larger mines in the district. In these latter, one sanitary privy underground would be a convenience and tend to check ground pollution. Such a privy could be cheaply constructed having removable containers (empty powder boxes with a layer of sawdust within) which could be hauled to the surface daily and burned. This is a cleanly, cheap, and efficient toilet system where only a small number of men are employed. In this connection, comment on mine privies is not out of place. At most of the mines there are privies on the surface, within easy access of the shaft or the change house. Some of these are clean and well kept; others are not clean, are not well kept, are in disrepair, and are a nuisance in every respect. Wretchedly insanitary privies are only too common everywhere in this district, and those seen at the mines were often no exception to this rule.

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DRINKING WATER.

The water keg with a common drinking cup is still to be seen, as is the keg with a small spigot which the men raise to their lips to drink from. A number of mines have done away with the keg and the cup. In view of the prevalence of tuberculosis among the miners, the danger of direct infection from common drinking contrivances is especially great and especially to be condemned. There are still far too many of these menaces to health in evidence. The effort to allay rock dust is resulting in water being piped throughout the mines more and more, and such lines may furnish water suitable for drinking also. Drinking devices made from upturned spigots were seen in several places. However, a plain spigot, turned up and having no guard attached is sanitary in appearance more than in reality, as the men are apt to put the end of the spigot directly in their mouths when drinking. The maintenance of common drinking devices in mines (and in stores, factories, and public buildings) should be forbidden by State law. In mines employing only a few men and where water is not piped in, each man should bring his own drinking water in a bottle or other container. The temperature in the mines is not such that a constant supply of drinking water is imperative.

CHANGE HOUSES.

The value of change houses is not properly appreciated by the miners themselves, if the extent to which the houses are used is an indication. A great many men do not change their clothes on coming to the surface after a shift, but go to their destination in the clothes in which they have been working. The proper appreciation of the necessity of changing wet clothes, especially when the weather is severe, is a matter on which the miners need education. Several mine operators have erected commodious and well-equipped change houses only to have their proper use disregarded and the fixtures broken. The advantage to be gained by a wash and a change to clean dry clothes after work is a real one that makes for health and lessens exposure, but many, if not most, of the miners seemingly have not realized this, even where opportunity has been offered. The disregard shown by employees of companies that have erected change houses has probably influenced other operators to refrain from erecting or equipping similar buildings.

The value of change houses is a subject that can be handled in a general campaign of education among the miners; the necessity for such a campaign is great, and it is to be hoped that it will be undertaken in the near future. Mines that have no change houses should erect them. A plain wooden building, properly heated and having running water for wash purposes, is all that is essential. Shower

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baths, individual lockers, and otherwise elaborate structures, although of undoubted benefit where there are sufficient reasons for erecting them, are naturally not to be looked for where only a few men are working; but a warm shelter for changing clothes should be available, even at small mines. The exposure resulting from men going home a considerable distance in wet clothes in cold weather undoubtedly furthers disease, particularly tuberculosis, and to induce appreciation of this by proper education of the miners is one of the things that will help to reduce the prevalence of pulmonary tuberculosis in the district.

NOONDAY DINNER HOUR

The State mining laws provide that there shall be an hour given at noon as dinner time for the men. It is customary for the men to hurry through their dinner in 20 minutes, rush back to work, and apply the time saved to getting off work earlier in the evening, but the efficiency of the men and their health, in other words the interests of both operator and miner, would be preserved better by a proper observance of the noonday dinner hour. The men in this district, especially the shovelers, work very hard, and a proper rest and a proper time to eat at noon is exceedingly important in preserving normal health. This is another matter on which the men themselves need education, though there is no apparent reason why the operators should not enforce the law as it stands. Their failure to do so naturally has been in deference to the wishes of the men. It should be understood that the men come to the surface to eat and rest and that the noonday rush, especially for men that do hard work under conditions that at the best are none too good, is, like the common drinking cup, unnecessary and indefensible.

EFFECT OF ROCK DUST.

The mining operations that are responsible for rock dust, and the practical methods for allaying dust have been considered elsewhere in this report. The influence of rock dust in the sheet-ground mines as a factor in the prevalence of tuberculosis can hardly be overestimated. Although the general causes that tend to produce high incidence of tuberculosis (bad housing, alcoholism, and poor working conditions) are fairly well defined and are more or less in evidence in Jasper County, the flint dust constitutes an unusual element of danger, and it would seem reasonable to attribute to this dust the unusual prevalence of tuberculosis in that district. Dust, regardless of its nature, is nearly always injurious to the lungs to a certain degree, as statistics of dusty trades will show. The hardness, sharpness, and insolubility of the rock dust in sheet-ground mines are sufficient evidence of its ability to harm lung tissue. These minute, sharp, flinty particles irritate the lung tissue, injure it, and render it

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susceptible to attack by the tubercle bacillus. One can hardly believe that men constantly working in such dust can escape with uninjured lungs.

It is not the purpose at this time to discuss at any great length the pathological changes produced in the lungs by rock dust, nor to enter fully into the discussion of miners' consumption versus tuberculosis. It is possible for a miner to have his lungs injured by rock dust, producing a condition that is not tuberculosis, and that this does occur is the opinion, so the writer was informed, of various physicians in the Joplin district. This also would appear to be the condition of the 25 men to whom reference has been made who were examined, and in spite of marked symptoms, offered very little or nothing on physical examination. So far as we know, irritation by rock dust produces a fibroid (thickened) condition of the lungs, leading to dyspnea (short wind) with cough, expectoration, lessened working ability, impaired general health, and sometimes loss of weight. If a tuberculous infection does not accompany this condition it undoubtedly follows in most cases and that before a very long time. This is the opinion of the writer, based on personal observation and the experiences of various physicians who have practiced in southwestern Missouri for many years. The State board of health does not recognize miner's consumption as a cause of death on death certificates. However, the relative incidence of the two diseases is a scientific rather than a practical question.

As regards public health the fact that a condition of miners' consumption may precede actual invasion by the tubercle bacillus influences in no way the sanitary picture of the district as a whole. It helps to establish rock dust as a contributory factor in causation; it does not influence the ultimate effect nor does it influence the application of remedial measures. Clinically, if the lungs have been injured by rock dust, the consequent tuberculosis is prone to be of the fibroid type, and the medical superintendent of the State hospital for tuberculosis states that these patients do not respond as readily to sanitarium treatment as the average run of patients, and that the outlook for them is nearly always bad. This is only natural, as lungs substantially injured by mechanical means have less chance of withstanding a tuberculous infection. So far as the public health is concerned the situation may be summed up as follows: Flint dust injures the lungs; injured lungs are particularly prone to tuberculous infection; much sickness and many deaths are recorded in the Joplin district from tuberculosis; reduce to a minimum the flint dust in the mines and this important predisposing cause of pulmonary disease in that part of the country will be practically eliminated.

It is not to be expected that immediate improvement in the vital statistics of the county will follow after this preventive measure has been

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adopted. There is far too much tuberculous infection spread throughout the district for quick results, but improvement will be apparent in time. When the mine operators of the Joplin district cooperate to devise methods of allaying rock dust, and, so far as practicable, put these methods into effect, they will free themselves from any liability to reproach that, in so far as working conditions are concerned, they are responsible for a menace to the health of their employees.

WORKING SYSTEM.

Certain elements of the working system, especially in the sheet-ground mines, attracted attention as being detrimental to the health of miners, and of the shovelers particularly. Shovelers work by the piece; that is, they are paid 5 to 8 cents for each "can" of ore they shovel. The cans have nominal capacities of 1,000, 1,250, or 1,650 pounds of ore, though the actual weight shoveled will average about 200 pounds less. The shoveler, depending on his strength and experience, can make from $3 to $4 and even $5 a day, considerably more than the skilled laborer (machine man), who makes $2.50 to $3 a day, a condition probably not found in many other mining camps. The mine operators claim that the piece system is the only one by which sufficient work can be gotten out of the men to make the business pay; this may be true, but such piecework when unrestrained except by the individual strength and willingness of the miner, is probably responsible for the physical breakdown of many men, and demands careful attention and consideration. The shovelers are often young, sometimes minors, and being anxious to earn as much as possible work extremely hard. It is the consensus of opinion among the operators that nowhere in this country is the efficiency of the shoveler (the amount of work per man) as high as in southwestern Missouri.

One can hardly realize the severity of this work without seeing it. Among the men who presented themselves for physical examination were many shovelers, who had practically a similar history. They had shoveled from two to six years; some had started when 18 or 19 years of age. Now they could shovel only 35 or 40 cans, where formerly they could shovel 60 to 70 and upward. Hard, constant work had broken these men down, so that at the ages of 22 to 30 they were already on the down grade. To shovel ninety 1,000-pound cans a day is not unusual, and some men questioned had shoveled as high as one hundred 1,250-pound cans in a shift. The shoveler is frequently his own trammer—that is, he pushes his full can out to the station and the empty one back again. Except for his hasty dinner at noon, he is incessantly at work the entire shift. Working thus at their full earning capacity day in and day out, it is not surprising that, with the added exposure to rock dust, these men should contract

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tuberculosis to an excessive degree. Especially must this be true when they start in while under age and before their bodies have fully developed.

The whole picture furnishes an example of burning the physical candle at both ends that is attested by the figures quoted at the beginning of this report. As far as could be ascertained from questioning mine operators, ground bosses, inspectors, and the miners themselves, the following course of events is typical of many miners. After a few years of shoveling, the shoveler finds himself beginning to get short-winded and his strength failing. When he comes to the point where he feels exhausted at the end of his day's work and feels "groggy" when he starts in the morning, he begins to rely on alcoholic stimulation to see him through, and if it has not already done so, alcohol now begins to lend a hand in furthering physical breakdown. The next step in the process is tuberculous infection, and when the shoveler finds that he is no longer able to make a living shoveling, he gets work as a machine man or machine helper. He finally becomes unable to work, and as these men usually work as long as they possibly can, death follows not long after cessation of work, most often when the man should be in the prime of life. Usually a fair-sized family is left behind and is apt to need charitable assistance. Although this sequence of events has not occurred in every case of fatal illness among miners, it is fairly typical of a great many.

To remedy constant excess work where these conditions prevail will be difficult. The present system suits both the operators and the miners. Any infringement of it would meet with opposition, more from the miner in all probability than from the operator. Conceding that a piece system is necessary for profit, it would seem that by placing a limit to the tonnage shoveled daily, the question of excessive work by the individual might be solved. It is probable that this could be done without working any great hardship to the operator, except when the price of ore is high and labor scarce. However, no reform of this sort can be accomplished easily, and it should be remembered that, after all, prevention is cheaper than cure, particularly in the case of tuberculosis, which exacts its financial toll from the State, the county, and the individual. Men under 20 years of age should not be employed as shovelers or machine men.

From both the social and the economic standpoint it would be unwise to prohibit minors from working in the mines, but their employment should be restricted to the lighter occupations of tramming, machine helper, etc. The present State law permits boys of 14 and older to work underground. The remedy for the main issue is one that will need testing before any legal enactments are made, but that reform in this matter is needed is apparent to the writer, to the State mine inspectors, and to others with whom this question was

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discussed. No one can doubt that, were the relationship between cause and effect as plain in the case of working conditions and disease as it is, for instance, between dangerous roof and accidents, the former would receive as much attention,both legislative and nonlegislative, as the latter, yet disease causes far more deaths and far more disability among the miners in the Joplin district than do accidents, and the disease is clearly defined and evident to all. The writer believes that this question of limiting the amount of work done one that deserves urgent consideration and attention.

SURFACE CONDITIONS.

HOME CONDITIONS.

Housing conditions of the miners were investigated by personal observation, house-to-house visits, and inquiry from physicians, insurance agents (industrial), and others. In general the housing is of poor quality, and often wretched. A number of neat, clean, well-kept homes were seen, both among the well and the sick, but these were the exception, especially where disease had begun to make inroads on the family income. Hundreds of miners' families live in small two and three room shacks unprovided with running water and having the privies that are usually most insanitary. Many of the houses are kept as clean as circumstances will permit, but as a whole they are of the type most readily associated with poverty and disease. The reason is not so apparent. The miners get good wages, a machine man making as high as $3 a day and a shoveler as high as $5. All shovelers do not make this amount, but it is not the lack of a living wage that is responsible for their poor housing, except where sickness has curtailed the income. The ground on which their houses or shacks is situated is often mining ground; they may own these homes and pay ground rent, or may rent outright; in either case the rent is not high. That many homes are situated on land taken up in mining claims may account for their poor construction and temporary nature. Homes in city limits have pipes for water supply; at other houses water is delivered by covered wagons into barrels situated in the front yard. Sometimes these barrels are covered and just as often are not. The quality of the water is excellent, being derived from deep wells.

As a class, miners apparently do not save and live well, so far as food is concerned, while they are making good wages. As soon as sickness appears they face destitution. They and their forefathers have lived in rather isolated and secluded places. Lack of proper instruction and lack of opportunity have contrived to make them unappreciative of better methods of living, and when transplanted to the large mining communities, and in receipt of better incomes,

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they still fail to improve materially. Far more intelligent than the average foreign laborer seen in other mining communities, in the main they do not take care of themselves nearly as well as the foreigner. There was evident at every phase of this investigation the necessity of an educational campaign among them to enable them to help themselves. Both underground and on the surface they fail to take advantage of the aids extended to them. Their readiness and willingness to improve are shown by the benefits of the visits of the visiting nurse, and where trouble has been taken to reach them and instruct them, improvement has followed. An educational campaign should be undertaken in Jasper County to cover both the necessity of obeying sanitary rules in the mines and the necessity of improving the sanitation of their homes. Above all is sanitary education needed in the public schools. In a community where large families are the rule, and children live together in small homes under conditions unfavorable for health, and where such instruction is often impossible in the home, unless the children can be taught the elemental rules of health in the school, the prospects for the coming generation are not much better than for the present one. To one who considers the widespread tuberculous infection, the crowded contact of children in their homes, and the insanitary habits of both parents and children, the extreme need of sanitary instruction is evident. The public school is the proper medium for such instruction, and the value of school instruction in affecting and improving home conditions should not be overlooked.

Alcoholism does not appear to be more prevalent in the Joplin district than in some other mining camps. Although the relation of alcoholism to tuberculosis is well known, one should remember that in many cases in which it takes an active part it is not a primary cause. Only when the vicious circle of disease, poor living, and poor working conditions is already established is alcohol most apt to appear as an active factor. Improve other abuses, and alcoholism will tend to diminish.

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CONCLUSIONS AND RECOMMENDATIONS.

By A. J. Lanza and Edwin Higgins.

CONCLUSIONS.

Following is a summary of conclusions arrived at as a result of this investigation:

1. The death rate from pulmonary diseases is unusually high among the miners of the Joplin district.

2. Poor housing, exposure, alcoholism, the use of common drinking receptacles, and overwork all tend to spread infection and lessen the power of the miner to resist disease, but the prime factor in causing pulmonary trouble is the rock dust in the mines.

3. Rock dust in the sheet-ground mines, although not made in great quantity as compared to mines with more restricted working places, is harmful to the miner for two reasons: (*a*) because he is exposed to it practically during his entire shift, and (*b*) because the dust is made up chiefly of particles of insoluble flinty chert with splintered and knifelike edges.

4. This rock dust is produced by the blowing of dry holes, squibbing, bowlder popping, drilling without water, shoveling, tramming, roof and pillar trimming, and the dumping of the bucket at the surface.

5. By observing certain precautions rock dust in the mines can be almost completely abated.

6. There are certain abuses connected with the piece system of work that demand attention and correction as far as practicable.

RECOMMENDATIONS.

1. The following means should be employed for the abatement of rock dust in the mines:

(*a*) Provide a water supply for every working face by the laying of a separate water line.

(*b*) Where drills are operated without water, attach to the hose leading to the face a 5 or 6 foot length of pipe with a nozzle from one-eighth to one-fourth inch in diameter. Make and enforce such regulations as will insure the use of this water spray for the purpose of wetting drill holes, the face, and the broken rock about the face. For the purpose of washing drill cuttings from drill holes, this hose

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may be attached to the long pipes now in use for blowing out drill holes.

(*c*) Where there is in use some type of drilling machine that provides for water passing through the core of the drill steel into the drill holes, make and enforce regulations that will insure the spraying of the face and broken rock for short periods at such times as the drill may not be in operation. For this purpose the water hose must be uncoupled from the drilling machine unless separate water connection is provided.

(*d*) Make and strictly enforce rules against squibbing and bowlder popping while the shift is underground and against the blowing of dry holes at all times.

(*e*) Improve ventilation by the opening of new shafts whenever practicable.

2. Do away with common drinking cups and kegs, and water pipes which allow the miner to bring his lips in contact with the orifice. Substitute the well-known sanitary drinking fountain when practicable, or have miners bring their own water supply in individual containers.

3. Do not employ as shovelers men under 20 years of age.

4. Through cooperation among the operators, provide a maximum daily tonnage for shovelers, so that they can not injure their health through overwork.

5. Provide a warm, dry, and clean place in which the miners may change their clothes.

6. Through intensive educational campaigns in the public schools, and among the miners themselves, disseminate information as to the harmful effects of insanitary practices and conditions, such as crowded living quarters, overwork, exposure, dissipation, the breathing of air polluted by powder fumes and rock dust, and the use of common drinking devices.

STATE LAWS FOR THE ABATEMENT OF CERTAIN SANITARY EVILS.

The writers believe that much can be accomplished toward increasing safety and protecting the health of the miner through educational work and by obtaining the miner's cooperation. However, it is realized that there are certain evils that can not be abated entirely by educational means.

Students of safety work in mining and other industries regard educational work as the chief factor in the prevention of accidents. In fact, the men who are most actively engaged in this work are almost unanimous in the belief that the greatest problem is to educate the miner and insure his cooperation. The average man, if taught that some act of his will result to his detriment, will usually

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make some effort to avoid such act. Experience has shown, on the other hand, that the average man will attempt to evade any law which tends, even in the slightest degree, to increase the amount of energy or labor which he must expend in the performance of his duties.

Many instances of this kind, both in the United States and foreign countries, could be cited but only one reference will be made here—namely, conditions existing in the State of Nevada, where a law was passed compelling mine operators to provide water at working faces. The operators generally obeyed the law, but it was found that the miners would not use the water provided. In a certain country, where the law made it a misdemeanor for the miner not to use water provided, it was reported that the miners used certain signals on the approach of an inspector, so that the water could be put in use during the trip of the inspector.

It is the belief of the writers that certain legislative provisions would be of value in abating rock dust and other evil conditions in and about the mines. The following suggestions are offered for consideration:

1. That all operators of dusty mines (the question as to what constitutes a dusty mine to be left to the State mine inspector) be compelled to run a water line, in addition to the air line, to each working face, and to provide water for the line.

2. That every miner be compelled to make use of the water so provided, for the purpose of wetting down the broken ore, the working faces, and the drill holes from which dust may be spread.

3. That the practice of breaking bowlders by means of powder or dynamite be prohibited, except when the shift has left the mine.

4. That the blowing of drill holes, without first thoroughly wetting them with water, be prohibited at all times.

5. That managers or operators of mines be prohibited from maintaining a common drinking device.

In addition to the above suggested provisions, the writers are of the belief that a workmen's compensation act would go far toward improving safety and sanitary conditions in the mines in the Joplin district.

NOTES REGARDING OPINIONS AND LAWS WITH REGARD TO HEALTH CONDITIONS IN FOREIGN MINES.

As indicating the consensus of opinion, and to draw attention to what has been done in other countries by way of legislation, there is included here a set of notes bearing on health conditions in mines in the Transvaal, Western Australia, Great Britain, and other countries.

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REPORT ON HEALTH OF CORNISH MINERS.

In the report [a] to the Secretary of State for the Home Department on the health of Cornish miners, the following summary and recommendations are set forth:

SUMMARY.

1. The death rate among miners living in Cornwall, which has always been very high in the case of men over about 40, has very greatly increased during the last few years among men of from 25 to 45.

2. The excessive death rate is shown by the statistics to be due entirely to phthisis and other lung diseases.

3. The recent increase in the death rate is also shown to be due to the deaths of men who have worked rock drills. The great majority of these deaths are attributable to the effects of rock-drill work in the Transvaal or elsewhere abroad; but a considerable number are attributable to work in Cornwall.

4. Nearly the whole of the deaths of rock drill men were due to "phthisis," and of the cases examined at least 74 per cent were tuberculous.

5. The predisposing cause of the present excessive mortality among metalliferous miners from lung diseases is evidently the inhalation of stone dust.

6. The dust is produced in the drilling of dry holes by rock drills, in blasting, in handling the ore, and in other ways.

7. The dust produced by rock drills can easily be prevented by even a very small water jet.[b] The dust from blasting in close ends can be laid by a powerful jet of water and air; and can in any case be avoided by the men. The inhalation of dust produced in blasting on the stopes can also be to a large extent avoided; while the dust produced in handling the ore can be mostly prevented by keeping the workings damp.

RECOMMENDATIONS.

1. That the use of percussion rock drills in hard stone without satisfactory precautions for preventing the dust being inhaled by the men be prohibited in all mines.

2. That special rules be established under the metalliferous mines regulation act by the management of every metalliferous mine, subject to the approval of the Secretary of State, for the carrying on of the work in such a manner as to reduce to a minimum the inhalation of dust by the various classes of men employed in the mine.

3. That special rules be also established under the same act, rendering it obligatory on the part of owners of metalliferous mines to provide and maintain in a suitable and cleanly condition a reasonable number of sanitary receptacles for the use of men in case of necessity underground, and also on the surface; and rendering it a contravention of the act unnecessarily to pollute any part of a mine with human feces.

The three main factors directly incidental to their occupation, which combine to produce diseases among the miners on the Witwatersrand are dust, infective processes, particularly tuberculosis, and in a lesser degree the fumes rising from the use (or abuse) of explosives.[c] This statement was made by Dr. Irvine in his evidence before the Mining Regulations Commission in May, 1908, and with that statement there must be universal agreement.

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[a] Haldane, J. S., Martin, J. S., and Thomas, R. A., Report to the Secretary of State for the Home Department on the health of Cornish miners, 1904.

[b] A jet with an orifice of one-twentieth-inch diameter directed into the hole was recommended by the signers of the report. It may be pointed out, however, that this was prior to the time of drilling machines furnishing water through the core of the drill.

[c] Penlerick, S., Ventilation and health conditions in the mines of the Witwatersrand: Jour. Chem. Met. and Min. Soc., South Africa, vol. 10, 1910, p. 59.

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Dust.—This constitutes the greatest danger which the underground worker has to combat. The sources of dust are: (*a*) Rock drilling, (*b*) blasting, (*c*) handling of rock. It must be acknowledged that the proper use of water in conjunction with rock drilling effectually allays the dust generated during the operation. In the face of this acknowledged fact, it is astounding that to-day this remedy has not, in many of our mines, been completely carried out. The proper use of water implies: (1) An adequate supply of clean water, (2) efficient application of the same.

With regard to this point, the law already has the power to insist on its enforcement (mines and workers' regulations, act 146. an amendment published in Government Notice No. 1278 of 1908).

MINING REGULATIONS IN SOUTH AFRICA.

The following extract [a] from an article in the Mining Magazine discusses provisions of the mines regulation act of 1912, that relate to ventilation and rock-dust conditions in South Africa mines:

The new mines regulation act embodied in act No. 12 of 1911, to consolidate and amend laws in force in the Union of South Africa, relating to the operations of mines, works, and machinery, and to certificates of competence, came into force on December 1, 1911. The old laws of the Provinces of Natal, Cape Colony, and Transvaal of the Orange Free State are either wholly or partly repealed.

On the subject of ventilation this law provides that samples of air taken under normal conditions, not less than one hour after blasting, must not contain more than 20 volumes of carbon dioxide per 10,000 volumes of air, except in special cases where there may be geological sources of production of carbon dioxide. The production of carbon monoxide must not exceed one volume per 10,000 volumes of air, and no detectable traces of the oxides of nitrogen are allowed.

The new regulations make a water spray or some other suitable method for allaying and removing the dust imperative.

MINING REGULATIONS IN NEW ZEALAND.

The mining act of 1906, No. 120, New Zealand (sec. 241) provides:

No female person of any age and no male person under the age of 14 years shall be employed for hire in any capacity in or about a mine: *Provided*, That this shall not apply in the case of clerical employment.

Article 243 prohibits employment of persons under 18 years as lander or brace man.

Article 254 contains the following provisions:

Ventilation to such an extent as is prescribed shall be constantly produced in every mine to the extent that the shafts, winzes, sumps, levels, and working places of such mine, and the traveling roads to and from such working places, may at all times be in a fit state for working and passing therein; and in particular—

(*a*) In every case where quartz or other substances are crushed in a dry state, or where rock drills are used, there shall at all times be used in and about the battery or place where such crushing or drilling is done such appliances as in the opinion of the inspector shall effectually keep the air pure and prevent dust circulating in the place where such operations are being carried on, and for this purpose an adequate supply of water shall be provided: Provided that where either the owner or workmen's inspector is dissatisfied with the opinion of the inspector an appeal shall lie to the warden, whose decision shall be final.

[a] Editorial, Mining regulations in South Africa; Mining Mag., February, 1912, p. 123.

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(*b*) For the purpose of insuring full ventilation in underground workings the inspector may require any level to be connected with the next higher level by an uprise or winze.

The act of 1910 (No. 780), entitled "An act to amend the mining act of 1908," provides (art. 9):

It shall not be lawful for the owner or manager of any mine, or for any person in charge of the mine, to require any person who is employed in the mine, or applying to be employed, to be medically examined or to produce a medical certificate that he is in a good and sound state of health.

The following is the proposed standard of ventilation that has been recommended by the Royal Commission for Metal Mines in New Zealand:

A place shall not be deemed to be in a fit state for working or passing therein if the air contains more than 1 per cent carbon dioxide or less than 19 per cent of oxygen. The maximum temperature in any working place shall not exceed 80° F., wet bulb.

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PUBLICATIONS ON METAL-MINE ACCIDENTS.

Limited editions of the following Bureau of Mines publications are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should select only those publications that are of especial interest to them. All requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 75. Rules and regulations for metal mines, by W. R. Ingalls and others. 1915. 285 pp., 1 fig.

BULLETIN 80. A primer on explosives for metal miners and quarrymen, by C. E. Munroe and Clarence Hall. 1915. 125 pp., 15 pls., 17 figs.

TECHNICAL PAPER 29. Training with mine-rescue breathing apparatus, by J. W. Paul. 1912. 16 pp.

TECHNICAL PAPER 30. Mine-accident prevention at Lake Superior iron mines, by D. E. Woodbridge. 1913. 38 pp., 9 figs.

TECHNICAL PAPER 40. Metal-mine accidents in the United States during the calendar year 1911, compiled by A. H. Fay. 1913. 54 pp.

TECHNICAL PAPER 59. Fires in Lake Superior iron mines, by Edwin Higgins. 1913. 34 pp., 2 pls.

TECHNICAL PAPER 61. Metal-mine accidents in the United States during the calendar year 1912, compiled by A. H. Fay. 1913. 76 pp., 1 fig.

TECHNICAL PAPER 67. Mine signboards, by Edwin Higgins and Edward Steidle. 1913. 15 pp., 1 pl., 4 figs.

TECHNICAL PAPER 94. Metal-mine accidents in the United States during the calendar year 1913, compiled by A. H. Fay. 1914. 73 pp.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 8. First-aid instructions for miners, by M. W. Glasgow, W. A. Raudenbush, and C. O. Roberts. 1913. 67 pp., 51 figs.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1913. 16 pp.

MINERS' CIRCULAR 13. Safety in tunneling, by D. W. Brunton and J. A. Davis. 1913. 19 pp.

MINERS' CIRCULAR 15. Rules for mine-rescue and first-aid field contests, by J. W. Paul. 1913. 12 pp.

MINERS' CIRCULAR 17. Accidents from falls of rock or ore, by Edwin Higgins. 1914. 15 pp., 8 figs.

MINERS' CIRCULAR 19. The prevention of accidents from explosives in metal mining, by Edwin Higgins. 1914. 16 pp., 14 figs.

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